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VOL. XIX, PART I

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RAINFALL OF INDIA: A BRIEF REVIEW *†

...DAS, Director of Agricultural Meteorology, Meteorological Office, Poona

...LED discussion of Indian rainfall would fill volumes. In a short article ... present ... one can attempt is to take a bird's-eye view of the subject. ... of Indian rainfall is really a history of the well known south-west ... We have ... liable records for about 60 years. As judged by these records, ... dependability of rainfall in different parts of this vast sub-continent, and ... chances of success of agriculture in different parts of the country? How ... century ... the monsoon rainfall so conspicuously in excess (flood) or in (drought) ... cause widespread havoc and failure of crops? Which are ... regions in India with minimum of weather-risk? Do such risks occur at random ... there any regularity or law governing the time and place of their occurrence? What are the large scale and long-term measures which the State can undertake ... order to reduce weather-risks? In what parts of India will such developments ... practicable? ... These are some of the questions which deserve consideration. In what follows, reference will be had to self-explanatory diagrams and tables so as to ... ity

Physical and climatic features

Fig. 1 ... show the distribution of the mountain and river-systems and of ... normal ... rainfall of India. The areas of very heavy rainfall are to ... windward side of the Western Ghats, the hills of Assam, and the great ... er. These are the watersheds from which originate the major river s... the country. Elsewhere, in the plateau of the Deccan, the Gangetic plains ... India, and the plains of the Carnatic, the effects of orography are less pronounced or are completely absent and the rainfall is only moderate. In the north ..., the Punjab, N.W. Frontier Province, Sind, Baluchistan, and the desert of ...utana constitute the driest area of the country.

Table ... gives the normal rainfall in different seasons of the year and during the year as a whole in the 30 subdivisions into which India may be divided (see Fig. 3). The four seasons are: winter, December to February; summer or pre-monsoon, March to May; monsoon, June to September; post-monsoon, October to November. In columns (2) to (5) the figures within brackets are the seasonal amounts expressed as percentages of the annual rainfall.

A study of these figures reveals at once that India is truly the land of the monsoons. With the exception of Kashmir, the N.W. Frontier Province, and Baluchistan in the north, and SE Madras in the south, *a very large percentage of the annual rainfall over the country occurs during the south-west monsoon* (June to September). In the extreme north a good proportion of the annual rainfall is contributed by winter precipitation, whilst in SE. Madras nearly half the annual rainfall occurs during the post- or retreating monsoon period (i.e., after September).

* Reproduced with permission from the *Empire Journal of Experimental Agriculture* **XIV** (54), April 1946

† The article deals with undivided India

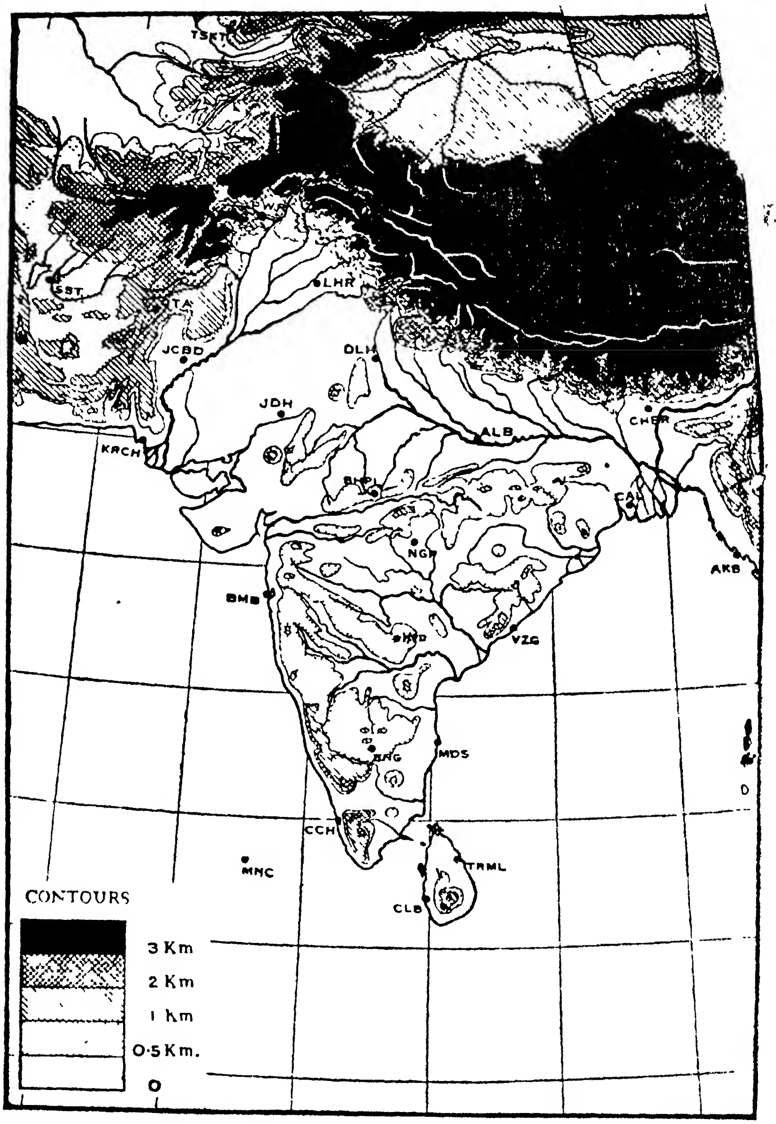

FIG. 1. Relief map of India

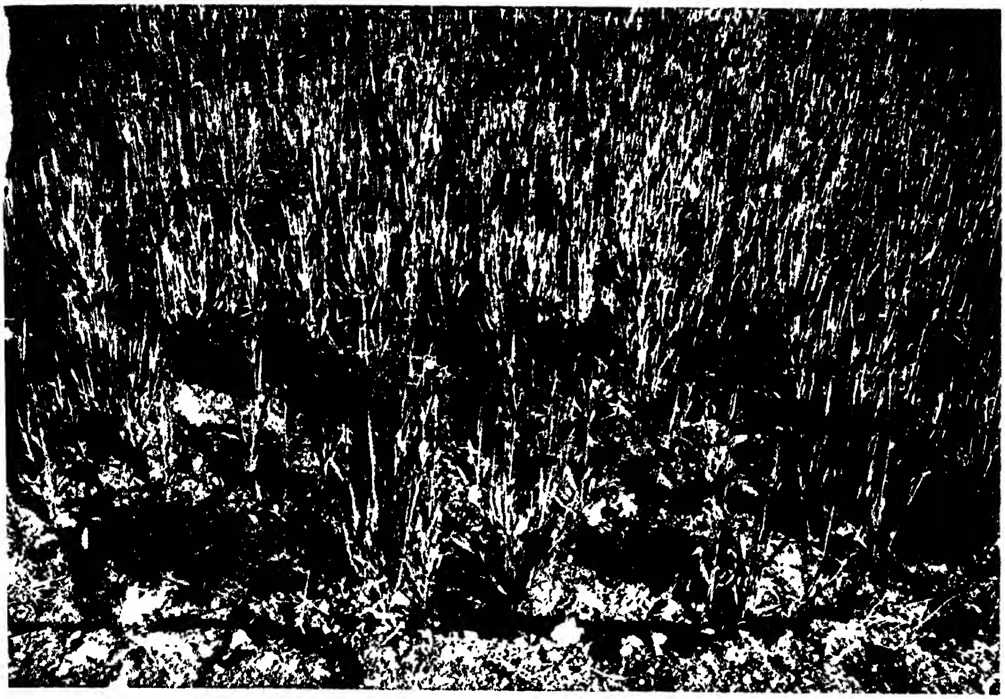

FIG. 5. Barley and peas from the Indian Agricultural Research Institute, New Delhi

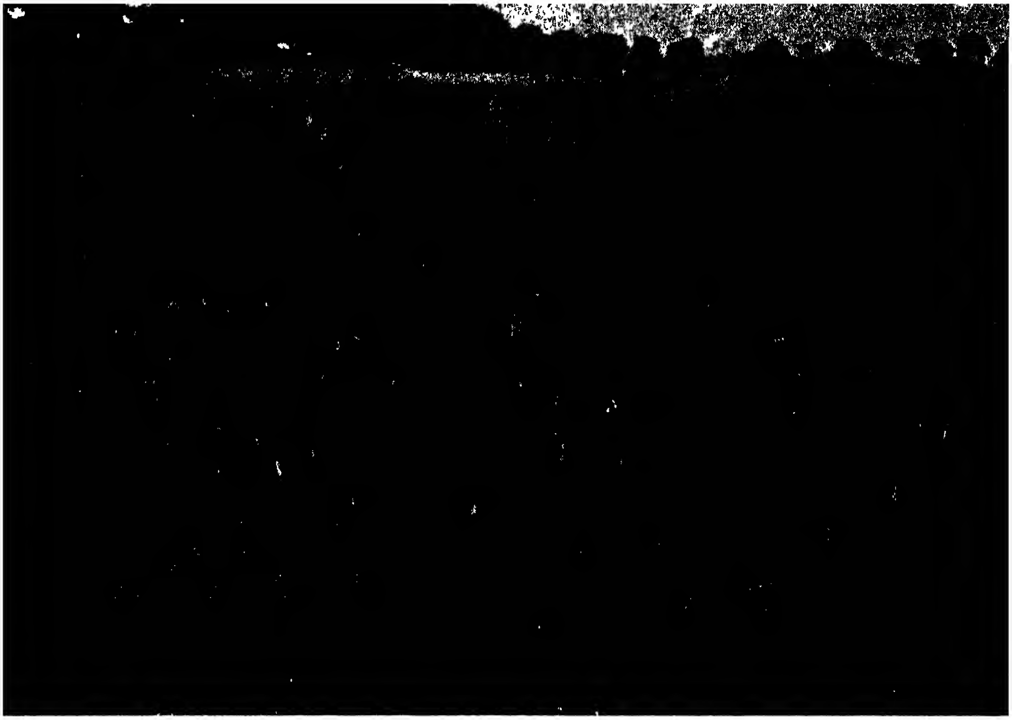

Fig. 3. Gram with wheat border of linseed (Bihar)

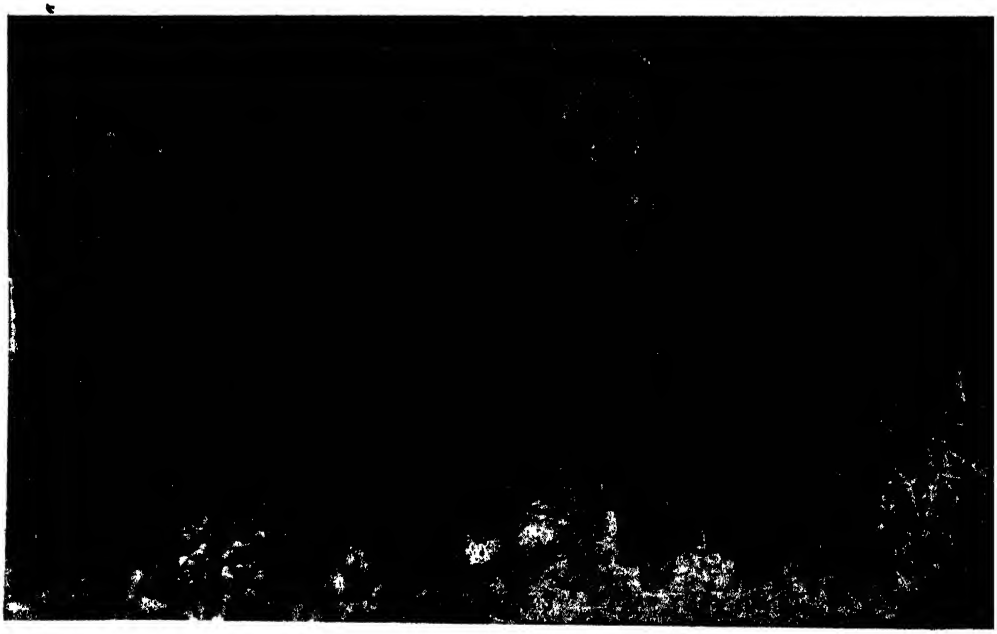

Fig. 4. Wheat, mustard and peas

Besides the setting in of the monsoon early in June, its extension into India during June and July, and finally its retreat southwards in September and October, we have also to consider the other major phenomena like cyclonic storms and depressions.

TABLE I

Normal seasonal rainfall in the 30 rainfall subdivisions of India in inches

Subdivision (1)	Winter December to February (2)	Summer or Pre-monsoon March to May (3)	Monsoon June to September (4)	Post-monsoon October to November (5)	Year (6)
1. Assam	2·38 (2·4) per cent	25·06 (25·7) per cent	64·26 (65·8) per cent	5·96 (6·1) per cent	97·66
2. Bengal	1·53 (2·0)	12·42 (16·5)	56·01 (74·5)	5·17 (6·9)	75·13
3. Orissa	1·82 (3·2)	5·62 (9·9)	44·49 (78·2)	4·98 (8·8)	56·91
4. Chota Nagpur	2·57 (5·0)	3·64 (7·1)	42·71 (83·4)	2·26 (4·4)	51·18
5. Bihar	1·41 (2·9)	3·30 (6·8)	40·96 (85·0)	2·54 (5·3)	48·21
6. U. P. East	1·53 (3·9)	1·12 (2·9)	34·44 (88·0)	2·04 (5·2)	39·13
7. U. P. West	2·27 (6·0)	1·36 (3·6)	32·98 (87·8)	0·97 (2·6)	37·58
8. Punjab, E. & N.	2·76 (11·9)	1·89 (8·1)	18·23 (78·4)	0·37 (1·6)	23·25
9. Punjab, SW.	1·28 (13·7)	1·36 (14·5)	6·58 (70·4)	0·13 (1·4)	9·35
10. Kashmir	9·12 (22·1)	9·09 (22·0)	22·19 (53·7)	0·94 (2·3)	41·34
11. N. W. F. P	3·36 (20·0)	4·18 (24·9)	8·65 (51·5)	0·62 (3·7)	16·81
12. Baluchistan	3·50 (45·6)	2·03 (26·4)	1·89 (24·6)	0·26 (3·4)	7·68
13. Sind	0·67 (10·4)	0·41 (6·4)	5·28 (82·4)	0·08 (1·2)	6·44
14. Rajputana, W.	0·62 (4·8)	0·56 (4·3)	11·74 (90·0)	0·12 (0·9)	13·04
15. Rajputana, E.	0·96 (3·8)	0·78 (3·1)	22·91 (90·9)	0·55 (2·2)	25·20
16. Gujerat	0·22 (0·7)	0·24 (0·7)	31·46 (96·2)	0·77 (2·4)	32·69
17. C. India, West	0·85 (2·5)	0·47 (1·4)	31·56 (93·8)	0·75 (2·2)	33·63
18. C. India, East	1·44 (3·7)	0·79 (2·0)	35·05 (90·9)	1·30 (3·4)	38·58
19. Berar	1·01 (3·1)	0·96 (3·0)	28·10 (87·4)	2·07 (6·4)	32·14
20. C. P. West	1·47 (3·2)	1·14 (2·5)	41·04 (90·4)	1·76 (3·9)	45·41
21. C. P. East	1·58 (3·0)	2·10 (4·0)	46·37 (89·1)	1·99 (3·8)	52·04

TABLE I *contd.*

Normal seasonal rainfall in the 30 rainfall subdivisions of India in inches—contd.

Subdivision (1)	Winter December to February (2)	Summer or Pre-monsoon March to May (3)	Monsoon June to September (4)	Post-monsoon October to November (5)	Year (6)
22. Konkan	0.28 (0.3)	1.85 (1.7)	102.45 (93.7)	4.75 (4.3)	109.33
23. Bombay Deccan	0.51 (1.7)	2.13 (6.9)	24.41 (79.1)	3.82 (12.4)	30.87
24. Hyderabad, N.	0.67 (1.9)	1.53 (4.4)	29.51 (84.5)	3.20 (9.2)	34.91
25. Hyderabad, S.	0.57 (1.9)	2.10 (7.0)	23.38 (78.1)	3.88 (13.0)	29.93
26. Mysore	0.73 (2.0)	5.47 (15.2)	22.27 (61.8)	7.54 (20.9)	36.01
27. Malabar	2.73 (2.6)	12.61 (12.2)	71.47 (68.9)	16.93 (16.3)	103.74
28. Madras, SE.	4.76 (13.6)	4.53 (12.9)	12.01 (34.2)	13.80 (39.3)	35.10
29. Madras, Deccan	0.74 (3.0)	2.42 (9.9)	15.27 (62.3)	0.09 (24.8)	24.52
30. Madras, Coast N.	1.69 (4.2)	3.44 (8.9)	25.03 (62.3)	10.00 (24.9)	40.16

Eastern depressions

The fluctuations in the intensity of the monsoon itself are to a large extent associated with a series of depressions which mostly originate (or, when they are coming from farther east, strengthen) at the head of the Bay of Bengal and travel in a north-westerly direction across the country towards NW. India, causing heavy rainfall along their track. The frequency of such depressions is three or four per month during the monsoon months (June to September).

Western depressions

During the period November to May a series of western depressions enter India through Baluchistan and the NW. frontier and move eastwards across North India towards NE. India (Assam-Bengal). These depressions cause cloudy weather and light rains in the plains with snowfall in the Himalayas and are followed by cold waves. Their frequency is, on the average, two in November, four to five per month during December to April, and about two in May.

(3) *Cyclonic storms*

The more severe cyclonic storms usually form in the Bay of Bengal and in the Arabian Sea in the transition periods April to June and October to December. They enter inland and cause considerable precipitation and damage due to high winds and, occasionally, tidal waves, in the coastal tracts. The mode of occurrence of these storms and their favourite tracts have been discussed in the publications of the India Meteorological Department. On an average one or two severe cyclones may be expected in the pre-monsoon period and two or three in the post-monsoon period.

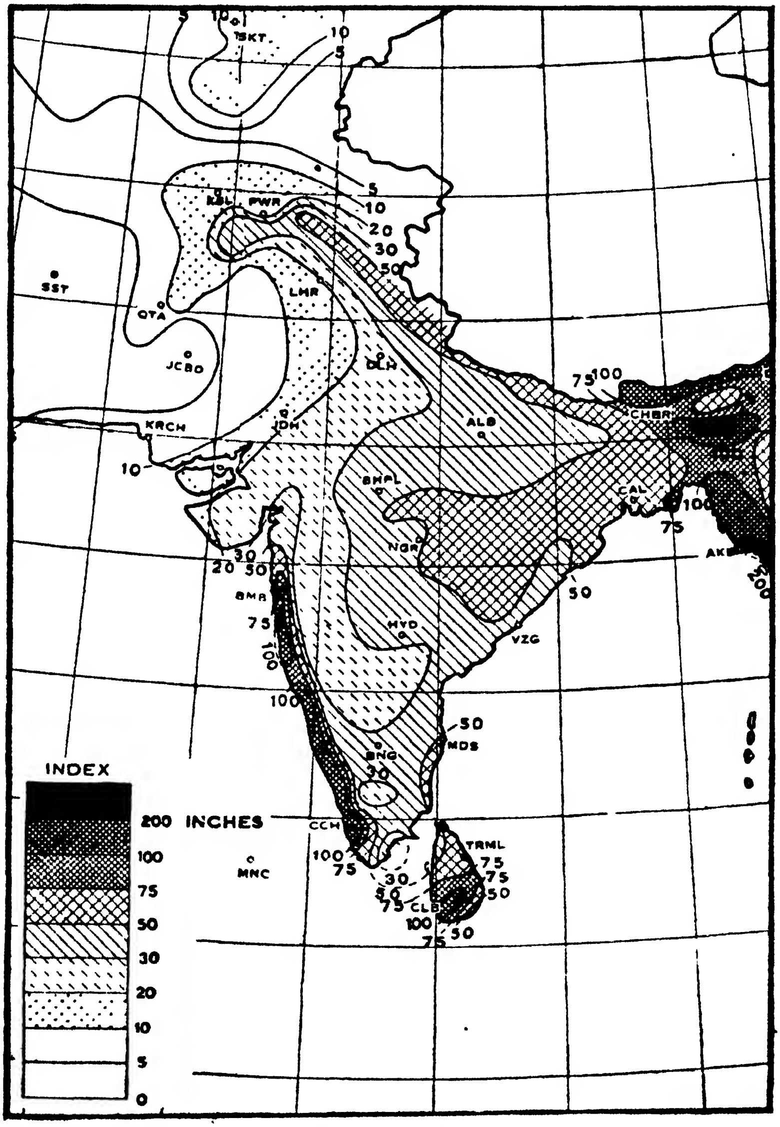

Fig. 2. Annual rainfall in India

TABLE II

Date of establishment of the S.W. monsoon along the West Coast of India

Year	Travancore-Cochin	S. Kanara	Ratanagiri	Kolaba
1891	May 27	June 3	June 19	June 21
1892	„ 22	May 24	May 29	May 31
1893	„ 22	June 4	June 10	June 10
1894	June 1	„ 2	„ 7	„ 7
1895	„ 8	„ 12	„ 14	„ 15
1896	May 30	May 31	„ 1	„ 1
1897	„ 30	June 5	„ 7	„ 7
1898	June 2	„ 3	„ 8	„ 8
1899	May 23	„ 7	„ 9	„ 10
1900	June 6	„ 8	„ 9	„ 9
1901	„ 1	„ 4	„ 7	„ 7
1902	May 31	„ 6	„ 7	„ 12
1903	June 8	„ 11	„ 12	„ 12
1904	May 29	„ 1	„ 7	„ 8
1905	June 6	„ 8	„ 9	„ 10
1906	„ 3	„ 6	„ 7	„ 8
1907	May 31	„ 5	„ 11	„ 11
1908	June 8	„ 10	„ 11	„ 11
1909	„ 1	„ 2	„ 3	„ 3
1910	May 28	„ 2	„ 3	„ 3
1911	June 1	„ 2	„ 4	„ 4
1912	„ 4	„ 6	„ 12	„ 12
1913	May 24	„ 1	„ 6	„ 7
1914	„ 28	„ 5	„ 13	„ 13
1915	June 3	„ 12	„ 17	„ 18
1916	May 26	May 27	May 31	„ 1
1917 . .	„ 26	„ 29	June 4	„ 5

TABLE II—*contd.*

Date of establishment of the S.W. monsoon along the West Coast of India—contd.

Year	Travancore-Cochin	S. Kanara	Ratnagari	Kolaba
1918	May 7	May 15	May 22	May 25
1919	,, 16	,, 26	June 4	June 6
1920	,, 27	June 2	,, 6	,, 6
1921	June 1	,, 3	,, 10	,, 12
1922	May 25	May 31	,, 10	,, 12
1923	June 4	June 11	,, 12	,, 13
1924	May 31	,, 3	,, 10	,, 12
1925	,, 27	May 28	May 29	May 29
1926	,, 28	June 5	June 9	June 10
1927	,, 23	May 27	,, 10	,, 10
1928	,, 31	,, 31	,, 5	,, 7
1929	,, 29	,, 30	,, 1	,, 6
1930	,, 21	June 7	,, 8	,, 9
1931	,, 23	May 29	,, 14	,, 14
1932	,, 14	June 2	,, 3	,, 3
1933	,, 22	May 28	,, 1	,, 1
1934	June 6	June 6	,, 10	,, 10
1935	,, 10	,, 10	,, 12	,, 14
1936	May 20	May 22	May 29	,, 1
1937	June 3	June 10	June 11	,, 12
1938	,, 1	,, 2	,, 2	,, 4
1939	,, 6	,, 6	,, 7	,, 9
1940	,, 7	,, 13	,, 16	,, 18
1941	May 23	,, 3	,, 14	,, 16
1942	June 4	,, 8	,, 12	,, 13
1943	May 12	May 14	May 21	May 21

THE SW. MONSOON

Date of establishment

As is well known, the success of Indian agriculture depends mainly on the monsoon rains; the farmer looks forward to the onset of the monsoon with great anxiety and prays for a timely and suitable distribution of rainfal during the season. The monsoon has been described in various publications of the India Meteorological Department. Figs. 1 and 5 show the *normal* dates of *onset* and of *withdrawal* of this monsoon in different parts of India. The actual dates ofonset as well as the intensity and distribution in time and space of the monsoonprecipitation vary from year to year. Table II gives the actual dates of establishment of the SW. monsoon in four areas along the west coast of the peninsula. It will be noticed that there is a considerable variation not only in the *dates* of establishment but also in the speed with which the monsoon current moves from the Travanore-Cochin area in the south towards Kolaba in the north (near Bombay). Table III below summarizes the information given in Table II.

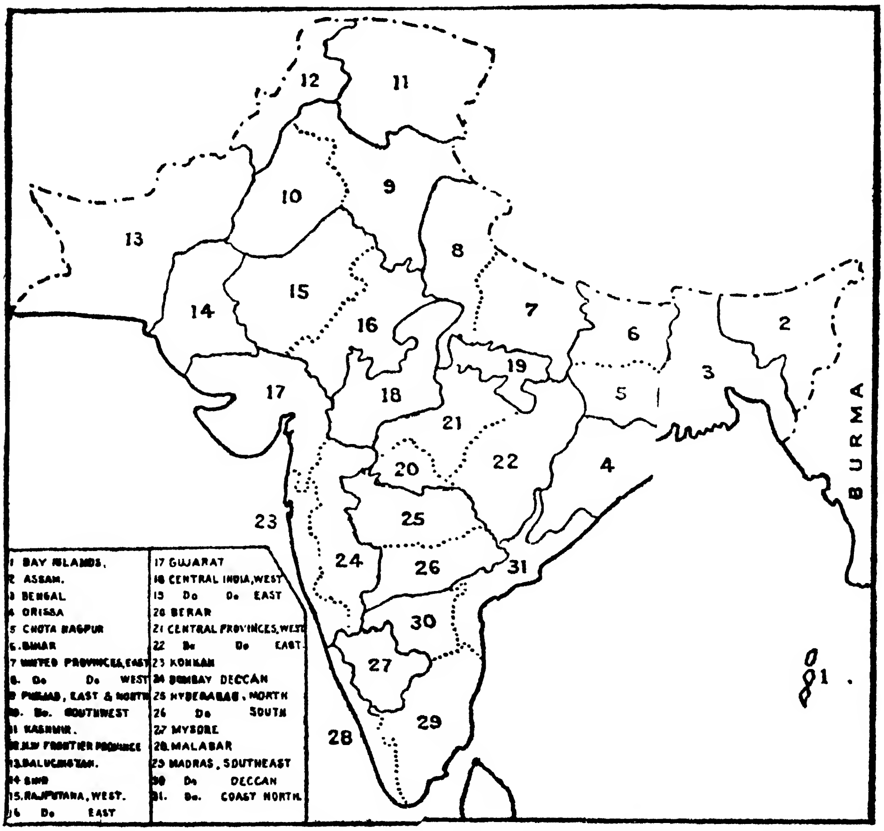

FIG. 3. Map of India showing the rainfall subdivisions

As the major agricultural operations have to synchronize with the monsoon rains, the importance of predicting the date of establishment of the monsoon in different parts of the country, the spells of rain and breaks which occur during the season, cannot be over-emphasized.

Survey of the past 70 monsoons (1875-1944). Frequency of drought and flood years

For this purpose the total rainfall during the period June to September is considered. If the deviation of the actual rainfall in a year is more than about twice the mean deviation, that year is defined as a year of flood or drought according as the departure is positive or negative.

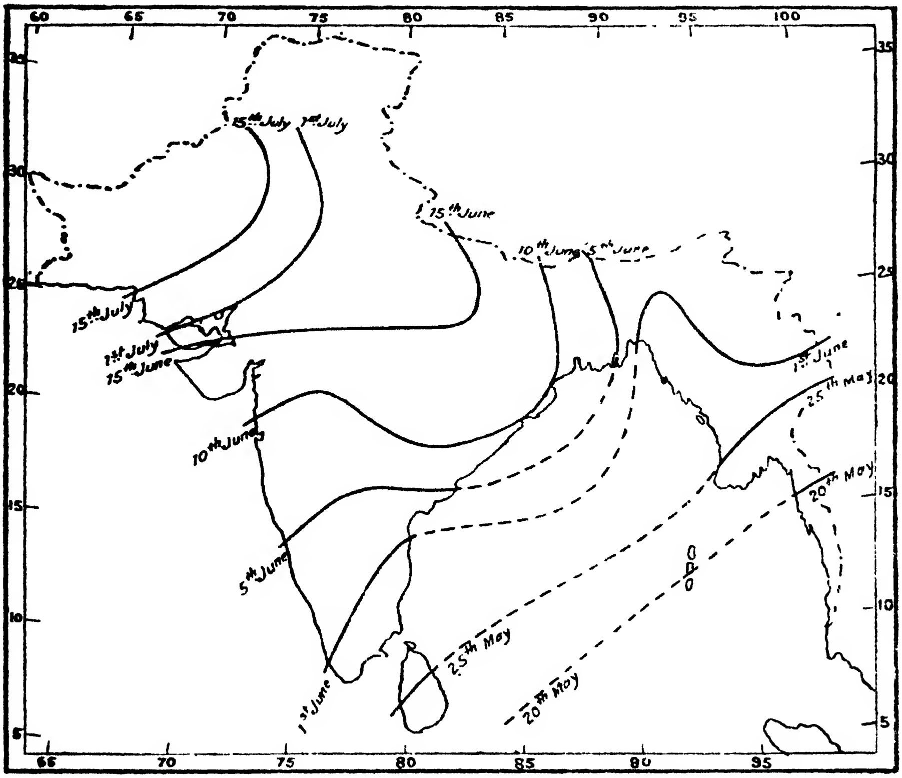

FIG. 4. Normal dates of onset of SW monsoon

E

TABLE III

Dates of establishment of the SW. monsoon along the West Coast of India

Area	Mean date	Standard deviation (in days)	Earliest date	Latest date
Travancore-Cochin . . .	May 29	7·0	May 7	June 10
South-Kanara	June 3	5·7	„ 15	„ 12
Ratanagiri	„ 7	5·4	„ 22	„ 19
Kolaba	„ 8	5·2	„ 25	„ 21

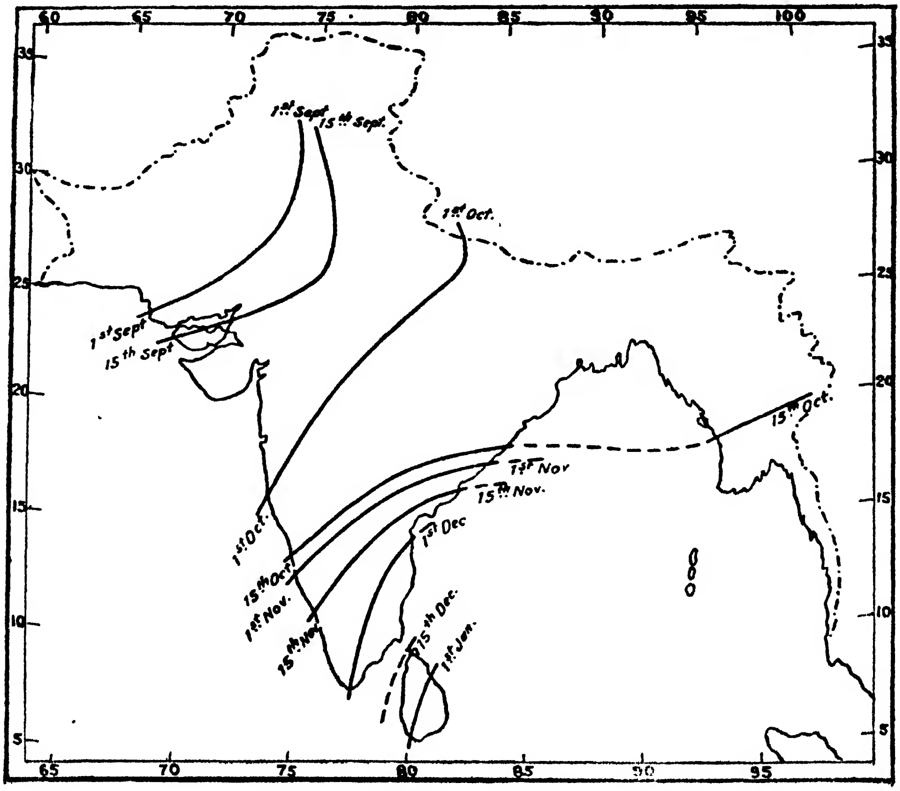

FIG. 5. Normal dates of withdrawal of SW. monsoon

Fig. 6 shows at a glance how the monsoon has behaved in the past 70 years in each of the 30 rainfall subdivisions of India. In the figure the filled circle indicates a flood, the open circle a drought, and the spaces which are blank are years and subdivisions with more or less normal monsoon rainfall. At the bottom of this diagram are given, for each subdivision, (1) the normal monsoon rainfall, (2) the means deviation, (3) the limit for abnormality, i.e., the amount by which the actual rainfall should be in excess or defect if it is to be labelled as 'abnormal' (flood or drought, as the case may be), (4) the total number of floods during the period 1875 to 1944, (5) the total number of droughts during the period 1875 to 1944 and (6) the total number of abnormal years (i.e. floods plus droughts) during the period 1875 to 1944.

These figures show that when we consider a sufficiently large number of years the frequencies of floods and droughts tend to equalize ; also, areas with a very low rainfall, e.g. Baluchistan, Sind, Rajputana, etc., are those where the total number of abnormalities is maximum ; in areas like the Konkan, Malabar, Bengal, etc., where the monsoon rainfall is above 40 in., the frequency of abnormal years comes down very much.

It is still more interesting to study the distribution of floods and droughts in the various subdivisions in each year. The years 1877, 1899, and 1918 stand out very prominently as years of general drought. It will be recalled that these were actually years of great famine and distress. The year 1920 was one of partial drought, only the north-west and the central parts of the country being affected. The years of general flood are 1878, 1892, and 1917. In two instances at least (1877, 1878, and 1917, 1918) droughts and floods occurred in adjacent years, but there is usually no regularity in time in the distribution of droughts and floods. The chances of one drought year being succeeded by another or a flood year being succeeded by another in a particular subdivision appear to be small. Areas of drought and floods are, however, associated into centres of defective or excessive rainfall in the years in which they do occur. For the rest, the reader can judge for himself from Fig. 6 how liable India is to the incidence of abnormal monsoons.

Before leaving this topic it will be interesting to compare the actual distributions of *weekly* rainfall during the monsoon season of the years 1917 and 1918, as they are likely to show up the contrast, not only in the total rainfall, but also in the distribution thereof. Fig. 7 shows the rainfall distribution in 1917 and 1918, for each of the main divisions : (1) NE. India ; (2) the United Provinces ; (3) NW. India ; (4) Central Provinces and Central India ; (5) North Peninsula ; (6) South Peninsula.

The dotted curves represent the normal weekly rainfall and the hatched area shows the actual rainfall. There is little contrast between 1917 and 1918 in NE. India as the rainfall was more or less normal in both the years. Over the other five divisions of the country, however, the contrast between the excess and the defect in 1917 and 1918 respectively was very marked.

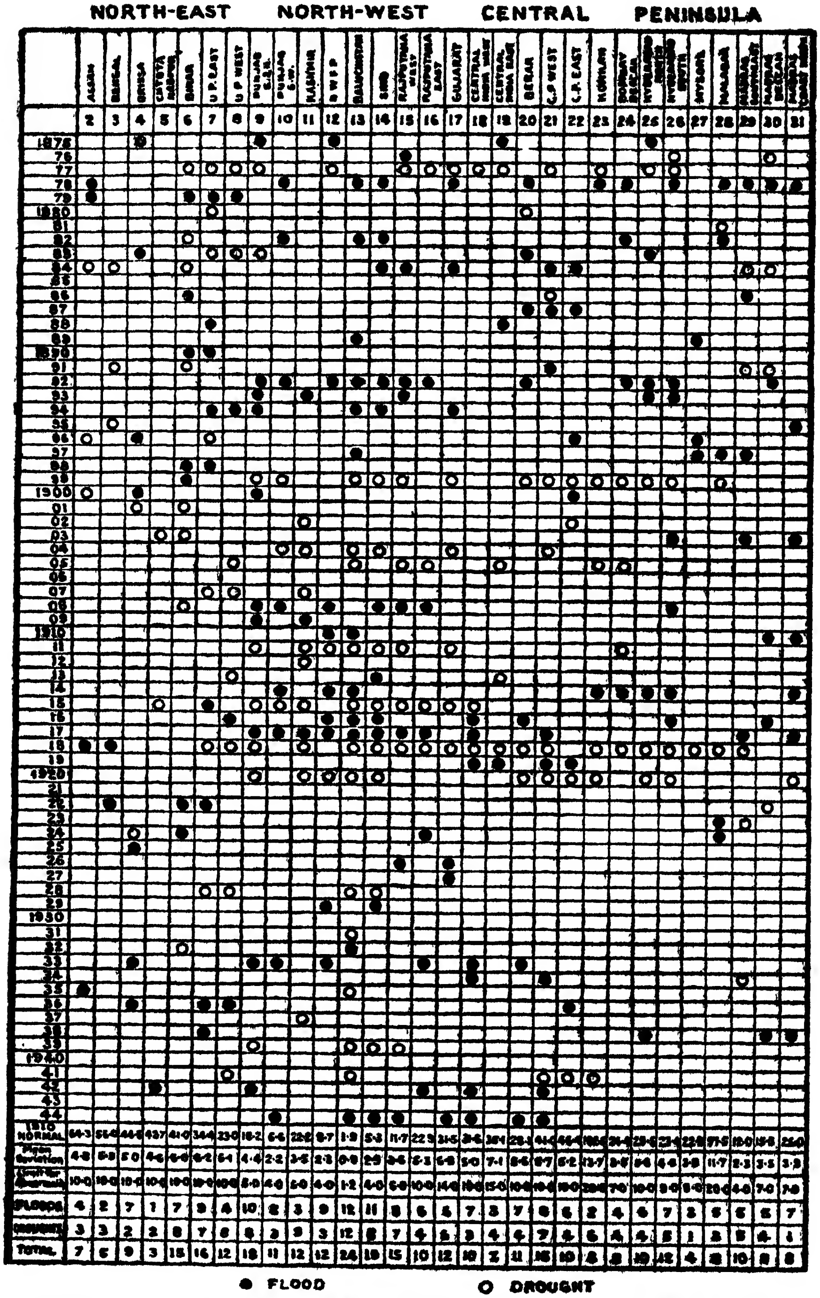

FIG. 6. Floods and droughts in India. Years of floods and droughts have for this purpose been defined as years with abnormality greater than twice the mean deviation.

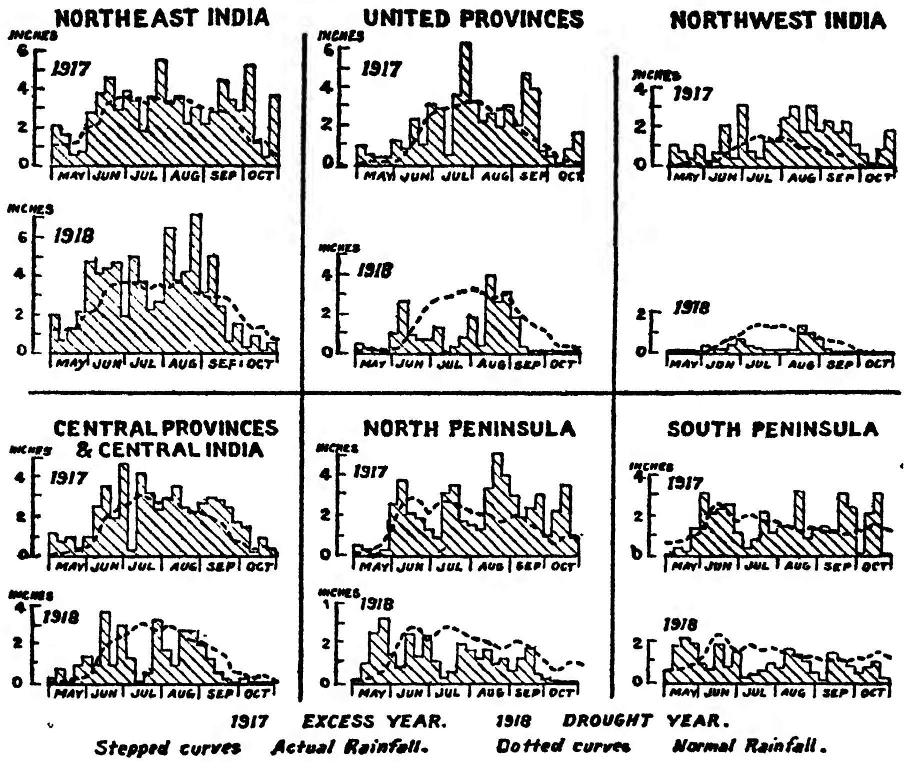

Fig. 7. Progress of the monsoon week by week

Contemporary relationships of monsoon rainfall in fifteen divisions

We have just seen that the monsoon rainfall varies from year to year both as regards the total rainfall as well as its distribution during the season. Administrators and others interested in the country as a whole may naturally inquire whether the effects of a deficiency in the monsoon rainfall in one part of the country is likely to be compensated by the effects of excess in some other part or parts.

TABLE IV

Monsoon rainfall June to September. Inter-correlations between pairs of divisions. Period 1875-1918

(*Vide* Table E, Memoirs of the Ind. Met. Dept., Vol 25, Part ii, p. 23)

Division	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV
I Barma	−0·47	−0·14	−0·05	−0·01	−0·09	−0·21	−0·29	−0·07	−0·26	+0·01	−0·01	−0·32	−0·15	−0·33
II Assam	..	+0·45	+0·27	+0·01	−0·16	−0·10	−0·13	−0·17	−0·24	−0·27	−0·40	−0·01	−0·11	+0·14
III Bengal	..	..	+0·56	−0·07	−0·07	−0·05	+0·04	−0·24	−0·31	−0·22	−0·45	−0·18	−0·15	−0·12
IV Bihar and Orissa . .	..	..	..	+0·31	+0·13	+0·06	+0·06	+0·05	−0·10	+0·04	−0·27	−0·01	−0·07	−0·16
V United Provinces . .	..	..	..	..	+0·49	+0·31	+0·06	+0·55	+0·30	+0·68	+0·33	+0·37	+0·07	+0·22
VI Punjab	..	..	..	.	..	+0·82	+0·56	+0·87	+0·59	+0·79	+0·59	+0·61	+0·11	+0·35
VII N.W.F.P. . . .	..	..	..	..	..	..	+0·65	+0·73	+0·59	+0·64	+0·46	+0·63	+0·22	+0·45
VIII Sind	..	..	..	..	..	..	..	+0·50	+0·65	+0·34	−0·34	+0·40	+0·24	+0·40
IX Rajputana . . .	..	..	..	..	..	..	..	..	+0·57	+0·51	+0·54	−0·57	+0·21	+0·40
X Bombay	..	..	..	..	..	..	..	..	..	+0·46	+0·58	+0·72	+0·53	+0·66
XI Central India . . .	..	..	..	..	..	..	..	..	..	..	+0·61	+0·40	+0·50	+0·21
XII Central Provinces . .	..	..	..	..	..	..	..	..	..	..	..	+0·55	+0·07	+0·18
XIII Hyderabad . . .	..	..	..	..	..	..	..	..	..	..	..	..	+0·38	+0·61
XIV Mysore	..	..	..	..	..	..	..	..	..	..	..	..	..	+0·80
XV Madras	..	..	..	..	..	..	..	..	..	..	..	..	..	..

Table IV below expresses the relation between the monsoon rainfall in each of the 15 divisions and the remaining divisions in the form of contemporary correlation coefficients. A positive coefficient in the table indicates the two areas concerned are likely to be affected similarly (i.e. both may have heavy rains in some years and deficient rains in other years). A negative coefficient would indicate that a decrease in one is likely to be associated with an increase in the other area. Looking at the correlation coefficients in each row, one notices that a vigorous monsoon over Burma tends to be associated with a subnormal monsoon over India (and *vice versa*). To a smaller extent. excessive rainfall over NE. India tends to be associated with a defect elsewhere (and *vice versa*). Elsewhere, in India, i.e., NW. India, Central India, and the Peninsula, the correlation coefficients are generally positive. indicating that departures from normal are likely to be similar over the greater part of India, as indeed the dot-diagram (Fig. 6) does suggest in regard to even pronounced abnormalities like floods and droughts.

Is India's climate changing ? Are there secular variations or periodicities in Indian rainfall ?

The longest meteorological records in India are of rainfall at the cities of Madras (from 1813), Bombay (from 1847), and Calcutta (from 1829).

The rainfall data of the above stations as well as of shorter series in the case of some 10 stations in Bihar were examined for periodicity. In some cases there were significant periods, but considering that neighbouring stations do not indicate similar periods, not much importance can be attached to these results. It may be worth while to examine the question more extensively for a network of selected stations or selected areas in India, for settling this point conclusively. Evidence so far collected does not, however. support the possibility of any regular periodicity in Indian rainfall.

Occasions of unusually heavy rainfall

The frequency of heavy rainfall over India has been discussed in a recent note by Doraiswamy and Mohamad Zafar (*Scientific Notes. Ind. Met. Dept.*, 7, No. 77). With reference to the heaviest fall in a day they find that :

(i) Falls exceeding 5 in. in 24 hours have occurred over the whole of India excluding NE. Baluchistan and parts of the NW. Frontier.

(ii) Falls have not exceeded 10 in. in 24 hours over most of the interior of the Peninsula and of Burma and in a few districts in the Central parts of the country.

(iii) Falls of 15 to 20 in. in 24 hours have occurred all along the west coast including Gujerat and Kathiawar, on the south Coromandel coast on the north Burma coast, in south Assam, in Bengal, and the foot of the Himalayas.

(iv) A few isolated falls of 20 in. and over have occurred in the plains.

(v) The greatest fall of over 40 in. in 24 hours has occurred at Cherapunji in the Khasi hills.

When heavy rainfall occurs consecutively on a number of days and particularly over the catchment areas of rivers, the magnitude of the ensuing floods may well be imagined. Ramkrishnan (*Scientific Notes, Ind. Met. Dept.*, *7*, No. 74) has estimated the total volume of water precipitated over certain areas in South India on days when they were under the grip of storms coming from the Bay of Bengal. The values given by him for one of these storms are quoted below :

Date	Area on land which had rain of 0·5 in. and more in sq. km.	Volume of water precipitated on land in cu. km.
21.10.30	60,150	1·9
22.10.30	53,730	1·6
23.10.30	71,540	4·9
24.10.30	103,660	8·0
25.10.30	133,740	6·5
26.10.30	141,620	7·1
27.10.30	342,520	11·9

Increasing forest-cover, checking erosion, delaying flood-peaks, and training the major rivers, etc., are problems which have begun to demand an increasing attention of the State.

Regional peculiarities in distribution of rainfall : climatic homogeneity

Even if we divide the country into climatically homogeneous tracts, judging from the normal rainfall there are still outstanding local peculiarities. This may be emphasized with the aid of a few examples.

Suppose that a weather forecaster expects a particular subdivision in the country to come under the influence of disturbed weather and forecasts rainfall over the area. Can he expect all the rain-guage stations to record more or less similar rainfall during a particular day ? Or will the rainfall be very variable ? This involves the question of rainfall variability in space and is very important from the weather forecaster's point of view.

We may also consider the point of view of an irrigation engineer faced by the problem of constructing reservoirs to serve the agriculturist's needs. Should he construct one big reservoir at a likely place or should he scatter a series of small reservoirs, casting his net wide as it were, so that one or the other of the reservoirs collects such rain as may fall over its neighbourhood ? How would the variability between stations in a given area compare with the variability between days of a month and with that due to random chance ?

In connexion with a recent inquiry, the variability of rainfall in the month of July 1942 was analyzed for a number of representative areas in India, taking 20 stations selected at random from each of these areas. Table V gives the analysis of variance between 'stations', days of the month, and 'residual' (due to random variability), for the Punjab, the United Provinces, the Central Provinces, Bengal, Rajputana, and Malabar. Column (5) gives the standard deviation of the variability 'between stations,' 'between days', and 'residual' or error. The next column gives the ratios of the variances, i.e.

$$\frac{\text{Variance between stations}}{\text{residual variance}} \text{ and } \frac{\text{Variance between days}}{\text{residual variance}}$$

Table V

Analysis of variance of rainfall in July 1942

Due to	Degrees of freedom	Sum of squares	Mean square (variance)	Standard deviation	Variance ratio : 'F'	Rainfall per day	Coefficient of variability per cent.
1. *The Punjab*							
Stations	19	21 1331	1·1123	1 55	3·73*	0·228 in.	680
Days	30	19 8421	0·6614	0 81	2 22*	..	556
Residue	570	169·8981	0·2981	0 55	..	..	241
Total . .	619	210 8736	0·3407	.	.	..	..
2. *The United Provinces*							
Stations	19	16·1105	0·8479	0 92	1·55	0·466 in.	197
Days	30	114·5280	3 8143	1·95	6·97*	..	418
Residue	570	312·1042	0·5475	0·74	..	..	159
Total . .	619	442·7427	..	..	..	..	..
3. *The Central Provinces*							
Stations	19	45·5754	2·3987	1·55	1·35	0·697 in.	222
Days	30	270·4394	9·1465	3·02	5·16*	..	433
Residue	570	618·9953	1·7715	1·33	..	..	191
Total . .	619	929·9901	1·5024	..	..	..	..

* Means significant at 1 per cent level

TABLE V—*contd.*

Analysis of variance of rainfall in July 1942.

Due to	Degrees of freedom	Sum of spuares	Mean square (variance)	Standard deviation	Variance ratio : 'F'	Rainfall per day	Coefficient of variability per cent.
4. *Bengal*							
Stations	19	41·4545	2·1818	1·48	3·62*	0·422 in.	350
Days	30	43 2002	1·4430	1·20	2·39*	..	284
Residue	570	343·4197	0·6025	0·78	..	..	185
TOTAL . .	619	428·1644	0 6917	..	..	..	..
5. *Rajputana*							
Stations	19	108·8073	5·7314	2·39	6·92*	0·417 in.	573
Days	30	46·2551	1·5418	1·24	1·86	..	297
Residue	570	471·9398	0·8280	0·91	..	..	218
TOTAL . .	619	627·0922	1·0131	..	..	..	..
6. *Malabar*							
Stations	19	85 4648	4·4981	2·12	5·53*	1 331 in.	159
Days	30	382·1749	12·7392	3·57	15·68*	..	268
Residue	570	463·1872	0 8126	0 90	..	..	68
TOTAL . .	619	930·8269	1·5038	..	..	..	..

* Means significant at 1 per cent level

If the variability 'between stations'. 'between days', and 'residual' are all of the same order of magnitude the ratio F will not be significant.

In the Punjab. Bengal. and in particular Rajputana and Malabar, the variability between stations is very significantly larger than that caused by random chance. In Malabar this variability is due to orography, whilst in Rajputana it represents a real climatic non-homogeneity. The variability between days is significant in all cases. In places like Rajputana it is indeed difficult to indicate where exactly rain would fall during a wet spell. The engineer would be well advised to construct a wide network of tanks in preference to a single big tank in such tracts.

IRRIGATION WORKS AND LARGE-SCALE RESERVOIRS, BUNDS, ETC.

Wherever the precipitation falling over a very wide catchment is drained into large river-systems like the Indus and Ganges, it is obvious that irrigation projects will be successful. as has indeed happened in the Punjab and Sind. In the United Provinces, besides canal irrigation, tube-wells are also being sunk on a large scale.

It may be pointed out that the large dry tracts of Peninsular India which are not fed by rivers can get adequate supplies of water for agriculture if the necessary irrigation-projects are set up at suitable localities in the catchment areas of the Western Ghats *which receive sufficient rains for this purpose even in years with weak monsoons.* Much of this water is now drained by rapids flowing into the Arabian Sea. If large reservoirs are built up on the Ghats over elevated areas, taking advantage of natural facilities for impounding the rain-water, the water so collected can be fed into the plains to the east of the Ghats through canal systems. This is a problem which the State alone can tackle ; it is full of large potentiality for the future of the arid tracts of Peninsular India.

In concluding this all too brief a summary of India's rainfall as affecting its agricultural potentialities, it may be appropriate to state that the India Meteorological Department is undertaking, in the very near future, to broadcast special weather bulletins and forecasts for the farmer. Seven Regional Forecasting Centres have been started. These will cater for the special weather requirements of their respective regions. Warnings for heavy and untimely rainfall, heat waves, cold waves, droughts, hail-storms, high winds, etc. will be issued, keeping in view the needs of the important crops of each region. In this new undertaking the Agricultural Meteorologist will maintain a close liaison between agriculture and meteorology.

PRELIMINARY STUDIES ON THE ESTABLISHMENT OF COLOUR STANDARDS IN RELATION TO SOIL CONSTANTS

By A. G. Asghar, C. L. Dhawan and K. D. Bhola, Irrigation Research Institute, Punjab, Lahore

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(With four text figures and plate I)

FROM the point of view of a cultivator, soil colour is regarded to be the first important characteristic of a soil. An average farmer judges the quality of a soil from the colour of the soil, and his verdict as to its usefulness for agricultural purpose or otherwise is primarily based on this observation.

The property of soil colour has now found its place in scientific research, and some work has been accomplished during the last few years in this direction. The treatment of the subject on a scientific basis has been done by developing various methods of measurements. The Soil Colour Standards Committee of the American Soil Survey Association found that nearly all the soils could be reproduced by rotating a colour disc containing the black, yellow, red and white segments. Hutton [1927] rotated the colour segments at high speed in a horizontal plane and held the soil over the rotating disc on a broad bladed spatula or in a small dish. This method was further improved by Shaw who rotated the soil on the same spindle as the colour disc.

For field descriptions of the soils, the United States Division of Soil Survey adopted a series of 57 standard colour names and colour charts describing these classes. These charts obviated the matching of the colour of the soil-sample with the colour discs and recommended the use of C.I.E. (Commission International d, Echirage) in the standardization of the soil colour values. Recently spectroscopy has also been introduced in measuring soil colour.

Attempts have been made to correlate the chemical composition of the soil and the soil colour. Mest [1910] and Leather [1898] attributed the black colour to titaniferous magnetite and humus. While Harrison and Rama Swami Sivan [1912] attributed it partly to humus and partly to hydrated double silicates of iron and aluminium. Ferrous oxide has no influence on soil colour and that it depends upon the silica ferric oxide ratio in the hydrochloric acid extract of the soil and that the red soil contains more ferric oxide and the black soil more of silica. Sante-Mattson [1941] has observed that soil colour may not be regarded as a sort of pigment present in the soil but a definite indication of constitutional differences in the composition and characteristics of the soil which are the result of lithospheric, atmospheric, hydrospheric and biospheric influences.

D

It will be seen from the literature referred to that during the past years the soil workers have been mostly engaged in the standardization of the methods for measuring the soil colour and to correlate the colour with the chemical composition of the soil. But no work has so far been carried out to correlate the soil colour with the soil performance and soil characteristics. The present investigation deals with the results of statistical analysis in an effort to correlate the soil colour and the physico-chemical properties of soils.

EXPERIMENTAL

An electrically rotating disc composed of segments of black, white, red and yellow standard colours, on thick paper, the speed of which could be adjusted by the help of rheostat was used for the comparison of the colours. Circular paper discs were so fixed by means of a screw in the centre of the disc that the area of any one colour could be adjusted suitably. A brass disc of 2·8 in. diameter was adjusted in the centre of the revolving disc. The soil to be tested was placed on this brass disc according to the following procedure.

A preliminary standardization of the method of preparing soil disc was necessary as is usually done in the case of chemical analysis. The soil was dried and sieved through 50 mesh sieve i.e. 0·25 mm. diameter and taken in a dish one day before the test was to be carried out. Water was added to make a thin paste and allowed to remain over-night. Next day the soil paste was applied gently with a brush to a semi-wet paper. The paste was allowed to dry under ordinary atmospheric conditions, and the soil coated paper so formed was pressed between two glass slabs. A disc of convenient size was then cut out, and a hole punched in the centre. The soil disc was mounted on the colour disc in the centre and kept in position by the help of the central screw. The colour disc having the soil disc was then rotated at a predetermined constant speed. During the rotation the soil disc developed a smooth colour. The segments of the colour disc were adjusted so that the soil disc exhibited the similar colour. The readings of the colour segments were taken on the circular dial which was graduated in angular degrees. Plate I shows the position of soil colour disc at rest and in motion. The soils were examined for clay, sticky point exchangeable bases, available phosphate and calcium carbonate by Puri's methods [1930, 1935]. The pH values were determined by the glass electrode using 1 : 5 soil water ratio.

Soil-sampling

Soil-samples (from 0-1·0 ft.) were collected from the various parts of India representing different types i.e. clay loam, lateritic, black cotton, forest soil, alkaline, and saline.

* * * * * * * * * * * * *

Diagramatic representation of analytical results

To facilitate comparison the results of analysis have been represented graphically. The results of clay, sticky point and exchangeable calcium have been plotted (vide Figs. 1-4).

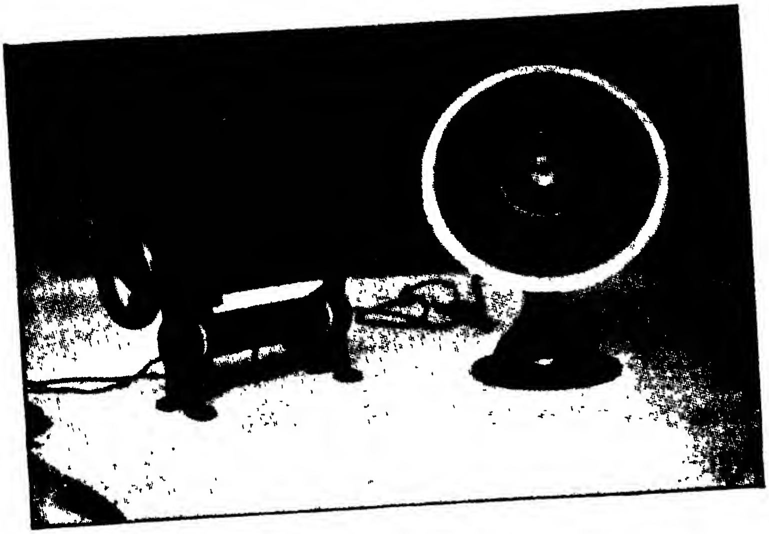

FIG. 1. Soil Colour Disc in motion.

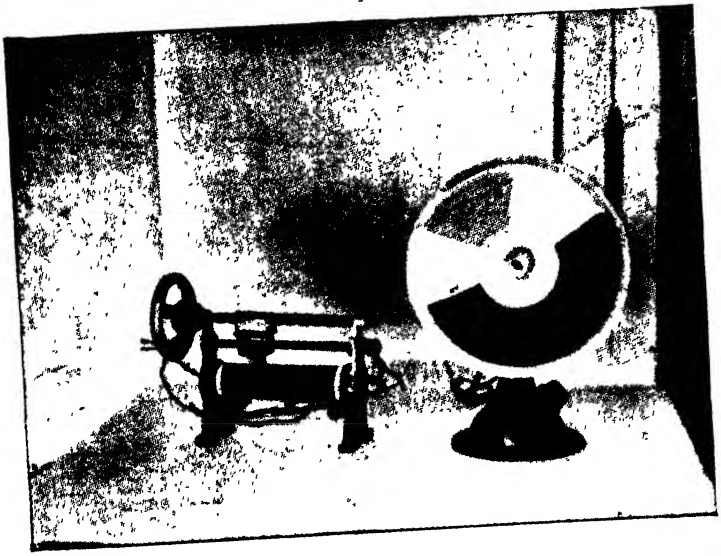

FIG. 2. Soil Colour Disc at rest.

* * * * * * * * * * * * * *

Statistical treatment of analytical analysis

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The statistical analysis of the observations is given in Table I. The following are the notations used in the statistical interpretation of the analytical results.

Variable 1 . .	Soil colour readings in degrees.
Variable 2 . .	Analytical results for the characteristic under consideration e.g. clay or sticky point etc. etc.
r 12 . .	Total correlation between variable 1 and 2.
A 12 . .	Percentage variance of soil colour expressible in terms of variable 2 alone.

Discussion of results

1. *Correlation of clay content and soil colour*

Fig. 1 shows the relation between the clay content and the black colour. The correlation between clay content and black colour is significant. The correlation coefficient is 0·6090, and positive. It shows that high clay content is associated with high black colour reading on the colour disc. The other colours do not bear any correlation with the clay content.

2. *Correlation of sticky point and soil colour*

The relation between the red colour and the sticky point is plotted in Fig. 2. The correlation with the sticky point is 0·7165 and negative. This shows that the high red colour is a characteristic of low sticky point. There is no correlation with the other colours.

3. *Correlation of exchangeable calcium and soil colour*

The relation between the black and red colours and the exchangeable calcium are represented in Figs. 3, 4. The correlation coefficients of exchangeable calcium with black and red colour are 0·7439 and positive and 0·3232 and negative respectively. The high black colour signifies high exchangeable calcium and the high red colour low exchangeable calcium. The correlation with the red colour is not very significant. It is interesting to note that the correlations of the black colour with the clay content and exchangeable calcium are positive in both the cases.

4. *Correlation of* p*H calcium carbonate, available phosphate and exchangeable (sodium+ potassium) with soil colour*

There is no correlation with any of the above constants.

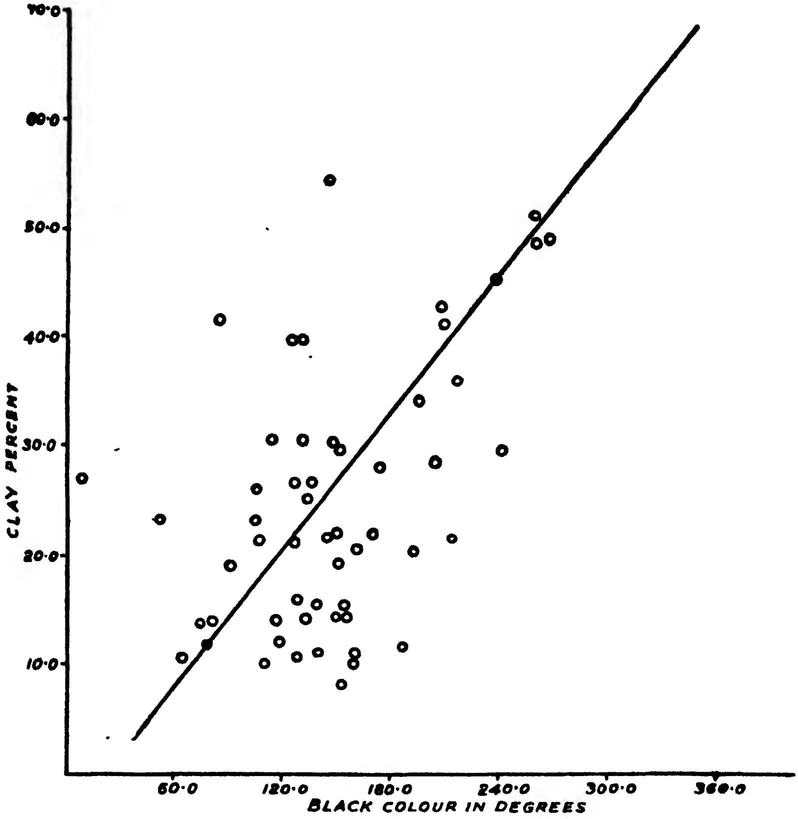

FIG. 1. Relation between clay and black colour

The regression equation is :

$$y = 0{\cdot}14x + 5{\cdot}3$$

where x=Black colour reading

y=Clay percentage

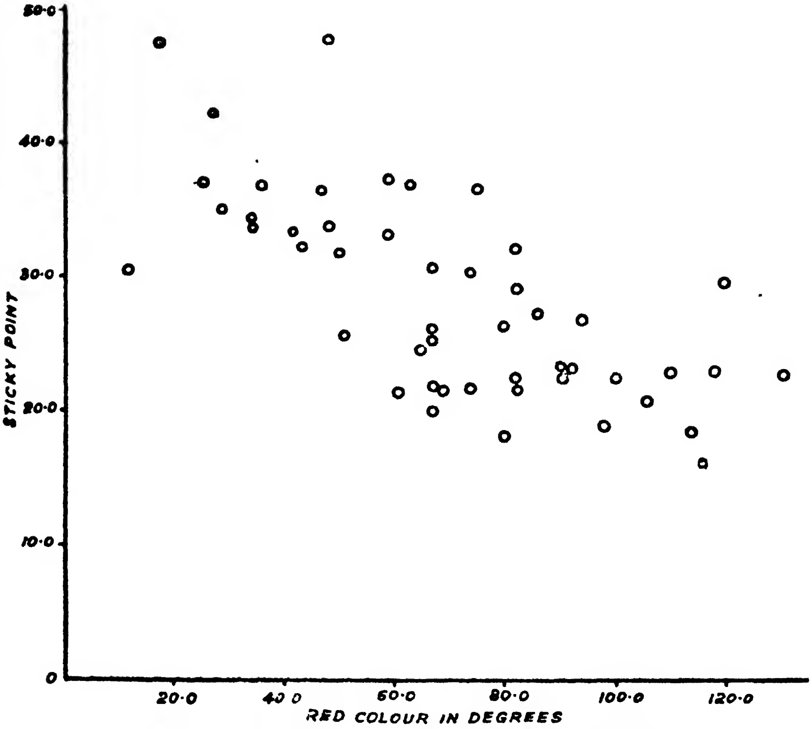

FIG. 2. Relation between sticky point and red colour

The regression equation is:

$$y = -0{\cdot}19x + 41{\cdot}3$$

where x=Red colour reading

y=Sticky point

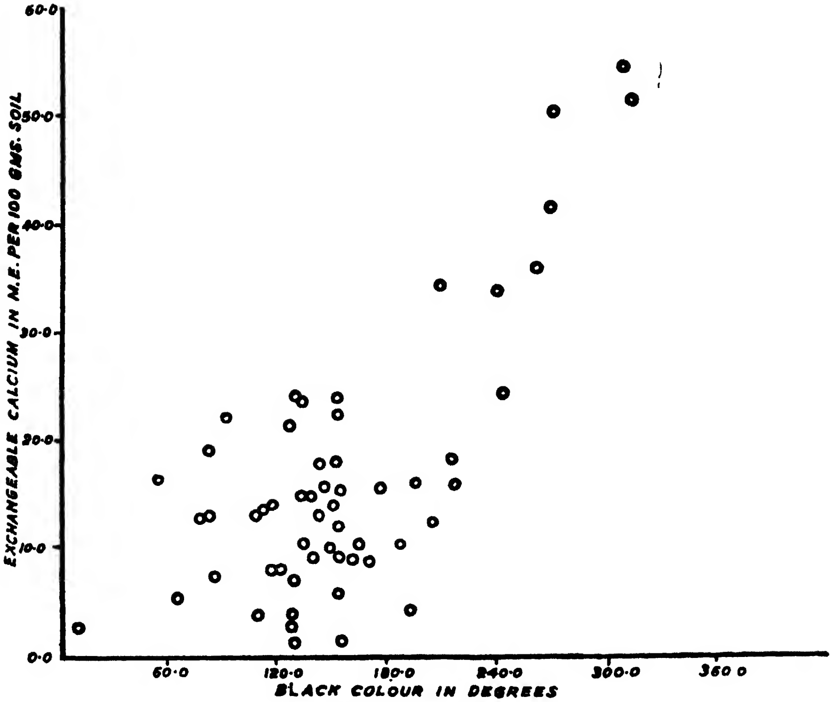

FIG. 3. Relation between exchangeable calcium and black colour

The regression equations are :

$y = 0{\cdot}15x - 6{\cdot}9$

$Y_1 = -0{\cdot}13x_1 + 26{\cdot}4$

where X = Black colour reading

X_1 = Red colour reading

and Y and Y_1 = Exchangeable calcium

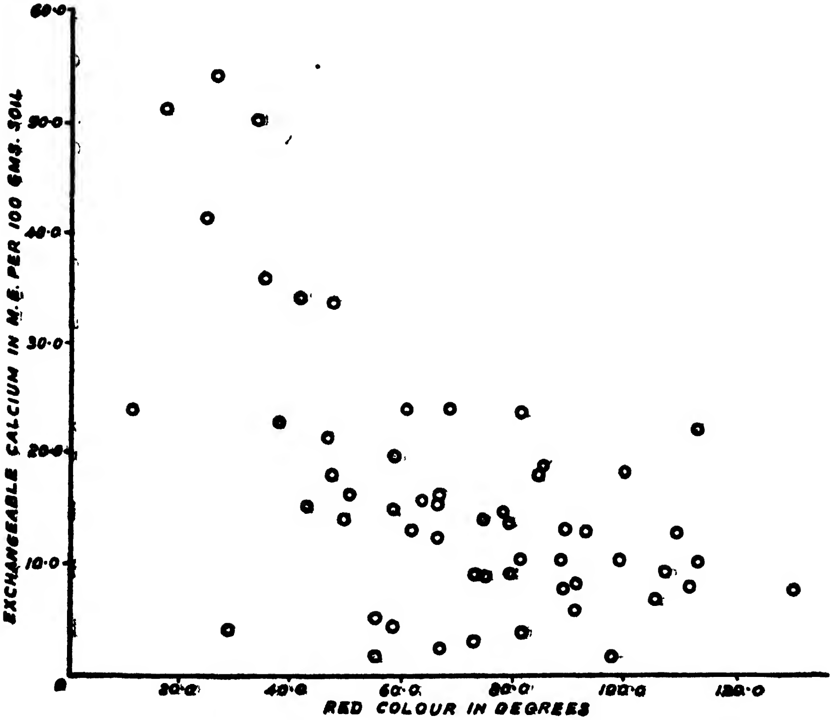

FIG. 4. Relation between exchangeable calcium and red colour

5. *Mutual correlation between clay and exchangeable calcium of the soils*

It has been shown above that there exists very significant correlation between the clay and exchangeable calcium content of soils with black colour. It is most probable that the characteristics which give significant correlation with black colour might have a correlation between themselves. It was therefore considered desirable to determine the mutual correlation of clay and exchangeable calcium contents of soils. The mutual correlation coefficient is 0·7892 and positive, which is highly significant. It indicates that a high exchangeable calcium is associated with a high clay content.

6. *Partial correlation coefficient between black colour and clay and exchangeable calcium*

It has been stated that the black colour is correlated with clay content and exchangeable calcium, and that the last two characters are correlated among themselves. The partial correlation coefficient between the two characters will therefore give us an idea of the association between two characters where the effect of the third is eliminated. The partial correlation coefficient between black colour and the clay content when the effect of exchangeable calcium is eliminated is ·0529 and the partial coefficient between black colour and the exchangeable calcium is 0·5404. In order to test the significance the values of t were calculated. The value of t for the former is 0·3749, which is insignificant and for the later is 4·542 which is significant. This shows that the black colour is independent of the clay and depends upon the exchangeable calcium.

Summary

The examination of the analytical data by the method of correlational analysis shows that significant correlation exists between clay and exchangeable calcium and black colour and between sticky point and red colour.

2. The correlation of exchangeable calcium with red colour though significant is not of high order.

3. The black colour is independent of clay content but depends upon the exchangeable calcium.

4. There is no correlation between pH, calcium carbonate, available phosphate and exchangeable Sodium-potassium with any colour.

5. As a result of this investigation the importance of the soil colour standard in relation to the physico-chemical properties of the soil has been brought out.

Table I

Correlations between soil colour and certain soil characteristics

Soil characteristics	Soil colour	No. of observation	r 12	A 12
Clay content	Black . . .	53	+0·6090	35·86
Sticky point	Red . . .	47	—0·7165	50·23
Exchangeable calcium	Black . . .	56	+0·7439	54·52
Exchangeable calcium .	Red . . .	56	—0·3232	8·80

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STUDIES ON BUNDELKHAND SOILS OF UNITED PROVINCES
III. PEDOCHEMICAL CHARACTERISTICS OF THE BLACK SOILS OF THE PLAINS

By R. R. AGARWAL, M.SC., D. PHIL., Agricultural Chemist, Government of United Provinces, and P. MUKERJI, B.SC.(AG.), ASSOC. I.A.R.I., Dry Farming Officer, U. P.

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IN previous communications [Mukerji and Agarwal, 1943; Agarwal and Mukerji, 1946] the soils of the district of Jhansi in the Bundelkhand tract have been described in detail from the stand-point of their genesis and three soil types differing from one another in general chemical, physical and mechanical characteristics were recognised. The district of Jalaun forms the most northerly portion of the tract and its landscape is entirely different from what one finds in the other parts of Bundelkhand. The district is a wide flat basin containing no hills but encircled by narrow rims of higher ground The entire basin is covered with fertile black soil.

The black soils are known to be calcareous, friable and very retentive of mois ture. The fertility is reputed to be high since crops of mixed wheat and gram are grown year after year without any manure or irrigation. The soils are, however, exposed to peculiar dangers due to their adhesiveness and unusual capacity to retain moisture. They become saturated with water quickly and when this happens tillage operations are very difficult. Besides, the black soil expands and contracts in a remarkable degree under the influence of moisture and dryness opening out into large fissures at frequent intervals.

Geologically the origin of these soils is ascribed to the subaqueous decomposition of trap rocks, but it has also been believed that it may really be due to subærial denudation of basaltic rocks and the impregnation of certain argillaceous soils by organic matter the latter ingredient together with iron giving it its black colour [Drake-Brokeman, 1910].

Agriculture

The agricultural system of the district though not of a high order excels in a general way the average of Bundelkhand. There are no irrigation facilities and all cultivation is done under dry farming conditions The chief *kharif* crops are *juar* and *bajra* alone or mixed with *arhar* and cotton. Of late the area under cotton has decreased considerably. *Juar* is the only staple *kharif* crop of Bundelkhand black soils. The chief *rabi* crops are gram and wheat, alone or mixed with one another. Linseed is also sown generally in fringes in the wheat fields.

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Climate

The climate of the district is very similar to that of Bundelkhand, details about which have already been described in part I of the series. The rainfall is slightly less than what is generally received at Jhansi. Records of rainfall have been maintained at the tehsil headquarters since 1864. Average figures for the three tehsils are given in Table I.

TABLE I

Average monthly rainfall data for Jalaun

(Average of 47 years in inches)

Tehsil	January	February	March	April	May	June	July	August	September	October	November	December	Total
Jalaun	0·50	0·42	0·29	0·14	0·33	3·17	10·24	10·49	4·99	0·62	0·07	0·25	31·61
Kunch	0·56	0·29	0·17	0·13	0·26	3·02	11·40	10·14	4·79	0·64	0·09	0·23	31·72
Orai	0·52	0·35	0·12	0·12	0·25	3·63	10·48	10·45	4·69	0·74	0·07	0·21	31·63
Average	0·53	0·35	0·19	0·13	0·28	3·27	10·71	10·36	4·82	0·67	0·08	0·23	31·65

The mean annual rainfall is 31·65 inches there being very little difference among the three tehsils. The precipitation is, however, very variable and this makes the agriculture of the tract most precarious. For, a deficient rainfall which brings about famine conditions is as disastrous as excessive rainfall in black soils. The months of June, July, August and September are the months which get most of the yearly precipitation, viz., about 29 inches. Only 2·65 inches are received in the remaining part of the year.

A careful survey of the soils of the areas which may be considered to be typical of the locality was made. Two soil profiles which were studied in detail are described in this paper. The samples of soil were collected horizon-wise. Morphological, chemical, mechanical and other data are presented in the body of the paper. The technique and the methods of analysis employed were the same as those described in part I of this series. Free iron in clay was estimated by the modification of Truog's method [1936] as suggested by Drosdoff [1941].

EXPERIMENTAL

Of the two soil profiles which were sampled for detailed investigations, one was from a pit dug on the Government Cattle Farm at village Ata in tehsil Orai and the other at village Satoh in tehsil Konch. Both the profiles were obtained from cultivated fields in which cultivation is being done without any irrigation or manure. The water table is about 80 to 90 feet below the surface and the texture of the soil is reported to be clayey.

Table II contains the morphological characters of the two profiles

TABLE II

Morphological characters of the soil profiles

Horizon	Depth	Sample depth	Description
			Ata profile
I	0 ft.–1 ft.	0 ft.–1 ft.	Black sticky soil tending to become ash grey on drying; no structure, compact, alkaline but non-calcareous
II	1ft.-3ft. 6in.	1ft.–2ft 4in. 2 ft. 4 in.–3 ft. 6 in	Same as above; slightly calcareous; more alkaline
III	3ft. 6in.–5ft.	3 ft. 6 in –4 ft. 8 in. 4ft. 8in.–5 ft	Ash grey tending to appear white; not so compact; less clayey than above; more alkaline and calcareous
IV	5 ft.-6 ft.	5 ft.–6 ft.	Calcareous, distinctly alkaline, loosely held calcareous material
			Satoh profile
I	0 ft.–2 ft.	0 ft.–1 ft. 1 ft.–2 ft	Black sticky soil becoming grey on drying: no marked structure; compact, alkaline: no effervescence with hydrochloric acid
II	2 ft.–4 ft.	2 ft.–3 ft 3 ft.-4 ft.	Same as above, darker in tinge; alkaline. slightly more compact. does not effervesce with hydrochloric acid
III	4 ft.-6 ft.	4 ft.–5 ft. 5 ft.–6 ft.	Slightly more alkaline, somewhat loose but clayey, very slight effervescence with hydrochloric acid

The profiles show all the characteristics of calcareous black soils. There are no clear cut horizon differences but the distribution of lime is slightly greater in bottom layers. The texture of the soil is predominantly clayey although the sub-soils are not so compact as the top layers. Nowhere, however, this compactness confers on the horizons an indurated character. The reaction throughout is alkaline although the bottom layers are more alkaline than the top layers.

In Table III are given the results of the analysis of the hydrochloric acid extracts of the soil samples from the two profiles.

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TABLE III

Analysis of the hydrochloric acid extract

(Per cent oven dry basis)

Ata profile

Particulars	0 ft.–1 ft.	1 ft.– 2 ft. 4 in.	2 ft. 4 in.— 3 ft. 6 in.	3 ft. 6 in.– 4 ft. 8 in.	4 ft. 8 in.– 5 ft.	5 ft.–6 ft.
Loss on ignition . . .	3·59	3 64	3·47	2·14	2·42	2·54
Total insolubles . . .	73·89	73·38	73·79	68·00	70·21	69·63
Sesquioxides . . .	16·16	16·82	11·71	14·75	14·25	14·47
Fe_2O_3	5·90	6·03	5·92	5·73	5·87	5·96
Al_2O_3	10·26	10·78	8·78	9 02	8·38	8·51
CaO	2·18	2·51	2·79	5·75	5·30	5·36
MgO	2·05	2·02	2·01	2·54	2·42	2·35
K_2O	2 29	2·35	1·16	2·26	2·20	0·80
P_2O_5	0·052	0·070	0·083	0·123	0·102	0·112
CO_2	0·69	0·90	1 29	2·67	2·60	2·96

Satoh profile

Particulars	0 ft.-1 ft.	1 ft.-2 ft.	2 ft.–3 ft.	3 ft –4 ft.	4 ft.–5 ft.	5 ft.-6 ft.
Loss on ignition . .	4·21	4·05	4·48	4·08	3·91	4·15
Total insolubles . .	74·71	73·53	75 84	72·28	72·57	73·41
Sesquioxides . . .	16·07	16·95	15·53	17·83	17·03	14·80
Fe_2O_3	6·05	6·35	6·48	6·41	6·43	6·34
Al_2O_3	10·01	10·59	9·15	11·41	10·59	8·46
CaO	1·83	1·63	1·77	1·85	1·77	1·71
MgO	0·75	0·98	0·84	1·85	1·74	1·01
K_2O	0·92	1·02	0·92	0·97	1·06	1·45
P_2O_5	0·116	0·095	0·117	0·106	0·116	0·095
CO_2	0·29	0·54	0·59	0·90	0·35	0·50

Moisture (not given in the Table) is more or less uniform throughout the profile except in the fourth layer in Ata profile and in the first layer in Satoh profile where it is slightly less in comparison. In the Ata profile the loss-on-ignition figures are constant in the first three layers and the next three layers show somewhat lower losses. In the Satoh profile loss-on-ignition figures are within limits constant. This shows that the distribution of colloidal matter is almost uniform in both the profiles. Acid insolubles do not also differ much with depth, only the top layers are slightly richer in these constituents. In regard to sesquioxides, the distribution of iron is uniform throughout although in the Ata profile alumina is more in the top two layers as compared with the bottom layers. Alumina is also slightly lower in the third and the sixth layer in comparison with other layers of the Satoh profile. Alkaline earth metals show some evidence of leaching. Both lime and magnesia have migrated to the bottom layers in the case of the Ata profile whereas only magnesia leaching is visible in the case of Satoh profile. The potash distribution is more or less uniform although there is more potash in the lower layers in Satoh profile. The Ata profile contains in general much more potash than the Satoh profile. P_2O_5 content is poor in both the profiles there being some evidence of phosphate leaching in the Ata profile. In general, the chemical composition of the soil material does not seem to vary much with the depth of the profile showing thereby that the forces of soil decomposition and consequent deposition have been extremely poor under the climatic conditions prevailing in the district.

The results of the mechanical and other general analyses are given in Table IV.

TABLE IV

Mechanical analysis (2 mm. sample) and general analysis

(Per cent air dry basis)

Ata profile

Particulars	0 ft.-1 ft.	1 ft.-2 ft. 4 in.	2 ft. 4 in.-3 ft. 6 in.	3 ft. 6 in.-4 ft. 8 in.	4 ft. 8 in.-5 ft.	5 ft.-6 ft
Coarse sand	0·270	0·675	1·78	1·45	1·00	2·08
Fine sand	27·34	24·21	24·77	27·79	30·44	30·96
Silt	24·00	28·00	28·00	23·75	22·75	24·00
Clay	40·50	36·25	35·25	33·50	33·00	31·50
pH in N KCl	7·8	7·3	7·8	8·2	8·4	8·4
Total nitrogen	0·071	0·059	0·057	0·048	0·043	0·042
Organic carbon	0·261	0·255	0·241	0·134	0·114	0·127
C/N ratio	3·7	4·3	4·2	2·8	2·6	3·0

TABLE IV—*contd.*

Mechanical analysis (2 mm. sample) and general analysis

(Per cent air dry basis)

Satoh profile

Particulars	0 ft.-1 ft.	1 ft.-2 ft.	2 ft.-3 ft.	3 ft.-4 ft.	4 ft.-5 ft.	5 ft.-6 ft.
Coarse sand	0·62	1·08	0·65	2·61	0·54	2·45
Fine sand	24·29	23·53	22·55	21·90	22·58	22·04
Silt	28·25	28·50	27·50	27·25	27·50	24·25
Clay	41·00	41·00	45·00	44·25	45·75	46·25
pH in N KCl	7·6	7·6	7·6	8·0	7·8	7·8
Total nitrogen	0·041	0·039	0·053	0·045	0·048	0·067
Organic carbon	0·285	0·030	0·291	0·300	0·316	0·300
C/N ratio	6·9	7·7	5·5	6·7	6·6	4·5

Both the soil profiles exhibit highly clayey texture. Clay content varies from 40 to 44 per cent in the top layers. In general, the textural variation in the profile has not been much showing thereby the absence of even physical translocation of the soil material. The low rainfall of the locality coupled with the calcareous nature of the soil has made it almost impossible for the clay to migrate to lower depths. In the Ata profile the clay content is more in the top layers as compared with the bottom layers. Reverse is the case with the coarse sand content. pH increases with depth in Ata profile due to the presence of carbonates of lime and magnesia. This increase is not pronounced in the case of the Satoh profile. The pH of the surface layers is, however, not very alkline. Total nitrogen content is not high but is more as compared to organic carbon giving narrow C/N ratios in the soil profile.

The nature of the exchange complex of the soil profile is shown by the figures of the exchangeable bases given in Table V.

TABLE V

Exchangeable bases
m. e. per cent
Ata profile

Particulars	0 ft.-1 ft.	1 ft.–2 ft. 4 in.	2 ft. 4 in.–3 ft. 6 in.	3 ft. 6 in.–4 ft. 8 in.	4 ft. 8 in –5 ft.	5 ft.-6 ft.
Calcium	29·36 (77·02)	23·68 (62·3)	17·12 (49·34)	10·32 (38·77)	9·20 (39·86)	8·00 (34·95)
Magnesium	6·22 (16·32)	10·12 (26·62)	10·93 (31·50)	9·23 (34·67)	6·23 (26·99)	7·78 (33·99)
Potassium	2·21 (5·80)	2 21 (5·82)	2·65 (7·64)	1·77 (6·65)	2·65 (11·48)	2·21 (9·66)
Sodium	0·33 (0·86)	2·00 (5 26)	4·00 (11·53)	5·30 (19·91)	5·00 (21·66)	4·90 (21·40)
Total exchangeable bases	38·12	38·01	34·70	26·62	3·08	22·89

Satoh profile

Particulars	0 ft.-1 ft.	1 ft.-2 ft.	2 ft.-3 ft.	3 ft.-4 ft.	4 ft.-5 ft.	5 ft.-6 ft.
Calcium	32·80 (82·72)	33·28 (81·49)	32·00 (78·64)	32·16 (80·68)	31·52 (77·59)	30·24 (74·73)
Magnesium	3·46 (8·73)	3 38 (8·27)	5 24 (12·88)	4 16 (10·44)	5·71 (14·07)	6·99 (17·27)
Potassium	1·76 (4 44)	2 42 (5·93)	1 98 (4 87)	1·98 (4·96)	1·76 (4·33)	1·54 (3·80)
Sodium	1·63 (4 11)	1·76 (4·31)	1·47 (3·61)	1·56 (3·92)	1·63 (4·01)	1·70 (4·20)
Total exchangeable bases	39 65	40·84	40·69	39·86	40·62	40·47

(Figures in brackets show percentage of the total exchangeable bases.)

A study of the distribution of the exchangeable bases in the soil profile clearly shows the calcium nature of the soils. Throughout, the predominating cation in the complex is calcium. Calcium and magnesium together constitute about 90 per cent of the total exchangeable bases in the Satoh profile. In the Ata profile the top two layers contain about 90 per cent of the divalent bases but the lower layers are richer in mono-valent ions. Calcium has a tendency to decrease and magnesium to increase downwards in the profile. In the Ata profile sodium concentration is very high in the bottom layers although the top two layers are not so rich in that base. Both sodium and potassium are more or less constant being in

moderately low quantities in the Satoh profile. It appears that the exchange complex of the soils is inherently rich in calcium but that there is some danger of its getting sodiumised specially in the bottom layers as has been found in the Ata profile.

The separated clay fraction was analyzed after fusion with sodium carbonate in the case of the Ata profile. Table VI contains the results of this analysis.

TABLE VI

Proximate analysis of clay

(Per cent air dry basis)

Ata profile

Particulars	0 ft.–1 ft.	1 ft.– 2 ft. 4 in.	2 ft. 4 in.– 3 ft. 6 in.	3 ft. 6 in.– 4 ft. 8 in.	4 ft. 8 in.– 5 in.	5 ft.–6 ft.
SiO_2	44·03	43·85	44·26	45·10	44·90	44·89
Al_2O_3	21·30	23·35	19·60	20·10	22·15	..
Fe_2O_3	9·20	9·60	10·00	10·40	10·80	..
MgO	2·46	2·46	2·17	2·57	3·17	3·77
K_2O	2·36	2·01	2·90	2·61	2·80	2·80
B. e. c. (m. e.)	75·0	76·0	71·0	69·0	75·0	67·0
Free Fe_2O_3	7·2	8·0	8·8	8·8	8·8	8·8
SiO_2/Al_2O_3	3·50	3·18	3·83	3·80	3·44	..

The results of the clay analysis show the uniform composition of the clay fractions of the different layers of the profile. The silica content of the clays from the various depths is constant. Alumina content varies from 19·60 to 23·35 per cent. Iron content also does not differ much but has a distinct tendency of accumulation in the bottom layers. Similar tendency is also exhibited by the magnesia and potash contents. Of the total iron content of the clay major portion happens to be present as uncombined with the silicate complex. The base exchange capacity is high, the average figure being about 72 m.e. per cent. Within limits, the silica-alumina ratios are constant in the soil profile.

Altogether, it appears that in the soils reported in the present paper the pedogenic forces have not been such as to lead to distinct soil types. The main factors responsible for this state of affairs are the low rainfall and the flat topography. High clay and low coarse sand contents in the profile signify much soil disintegration presumably under the influence of subaqueous weathering of the parent material. There has, however, been very little translocation of the weathered material to lower depths. Even physical transfer of clay to lower depths has been absent; consequently there are no clear cut horizon differentiation. The soil and the clay composition in the profile accordingly present a uniform picture throughout.

The soils are, however, rich in exchange capacity being of montmorillonite character and this fact confers on them their unusual agricultural potentiality and the inexhaustible fertility. Having been formed from calcareous parent material and being of ferro-magnesian in origin the exchange complex is ordinarily well supplied with divalent cations specially calcium. There seems, however, some evidence of the complex getting rich in sodium specially in the bottom layers and this degradation is likely to affect adversely the physical characteristic of the clayey soils. It is in this respect that proper care in soil management is necessary if the existing fertility is to be preserved over a long period.

Summary

Two representative soil profiles from district Jalaun in the plains of the Bundelkhand tract have been studied.

Chemical, mechanical and physico-chemical characters of the soil profiles have been discussed.

The profiles in general show very little translocation of the weathered material and hence the composition is more or less uniform throughout.

The analysis of the clay isolates shows that the average value of the SiO_2/Al_2O_3 ratios is 3·55 and within limits this value is constant in the soil profile.

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THE RELATIVE IMPORTANCE OF ORGANIC MANURES AND INORGANIC FERTILIZERS IN TROPICAL SOILS

By Dr S. Das, Indian Agricultural Research Institute, New Delhi

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(FROM a consideration of available evidence it would appear that the organic material decomposes progressively to humus under temperate conditions as a result of complicated biochemical and biological reactions in the soil; the three main effects of organic matter in the soil are due to (1) its content and availability of plant materials, principally compounds of N, P, K and Ca; (2) its influence on the activities of soil micro-organisms, and (3) the improvement of the physical condition of the soil.) These observations obtained under temperate soil conditions have led agricultural scientists in India to accept them as a basis for further work. They have found that the effects of organic matter in tropical soils seem much more ephemeral than in temperate climates owing probably to the much quicker rate of decomposition and the smaller end-products in the soil. The average nitrogen and carbon contents of Indian soils are 0·05 per cent and 0·6 per cent respectively. Similar figures for European soils are 0·15 per cent N and 3 per cent organic C. European soils are thus 5 times richer in humus content and still the demand there is for organic matter. This explains the disappointing nature of fertilizer experiments on Indian soils. The needs of Indian soils are evident and the data from manurial experiments portray the requirements correctly. (Cattle manure, green manure and other organic manures are valueable to soils, because they supply what is popularly known as humus which is so essential to maintain soil fertility. The cry for organic manures for Indian soils is even stronger and more imperative. because the disruption of organic matter is faster at high temperatures obtaining in India. The rate of destruction can be imagined when it is found that a soil at Coimbatore receiving cattle manure at 10 tons per acre per annum in two instalments continuously for 20 years, contains only 0·74 per cent of organic carbon as against 0·59 per cent in the unmanured soil.)

The results in Table I indicate the status of C and N in soils of cool and warm climates under manurial treatments and otherwise.

TABLE I

Status of C and N in soils of cool and warm climates.

Cool climates	C	N	C/N	Warm climates	C	N	C/N
Rothamsted—Broadbalk wheat—No manure since 1839	0·89	0·092	9·6	Gazira (Sudan)[1] .	0·4	0·03	12·6
				South Africa—[2] Winter rainfall region	..	..	15

Percentage of C and N and C/N rations in various surface soils (Cf. E. J. Russull—*Soil conditions and plant growth*. 7th ED. 1937)

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TABLE I—*contd.*

Cool climates	C	N	C/N	Warm climates	C	N	C/N
F. Y. M. annually since 1843	2·91	0·263	11	Transvaal—[3] Black loam	1·87	0·13	14·4
Woburn, 1876	1·49	0·155	9·6				
Woburn barley plots, 1932—				Siam—[3] Paddy soil	6·37	0·56	11·4
No organic manure since 1876	0·92	0·095	9·7	Iowa—[4]	..	..	12-13
				Average of Jenny's data[5]	..	..	9·2
F. Y. M. annually since 1876	1·23	0·123	10·0				
Aber, North Wales—							
6 grass[2]	3·22	0·35	9·2				
6 arable[2]	2·93	0·32	9·2				
50 English soils	..	..	10				
Poland[6]	..	..	10·4				

Percentages of C and N and C/N rations in various surface soils (Cf. E. J. Russell—*Soil conditions and plant growth.* 7th Ed. 1937)

1 Average of 42 samples, 1st foot. A. F. Joseph
2 W. E. Isaac (1935). *Trans. Roy. Soc. S. Africa*, 23, 205
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The rate of conservation of organic carbon by the continuous annual applications of organic manures to Pusa calcareous soils will be evident from the results in Table II.

TABLE II

Permanent manurial plots, new series, Pusa soils examined in 1947

Treatment per acre, annually since 1932	Average of 10 replications		
	C	N	C/N
A. No manure	0·28	0·034	8·2
B F. Y. M. at 8,000 lb.	0·37	0·045	8·1
C Rape cake at 40 lb. N	0·31	0·037	8·3

TABLE II—*contd.*

Old permanent manurial plots, A and B series, Pusa soils examined in 1947

Plot No.	Treatment per acre, annually since 1907	C (A series)	N (A series)	C/N (A series)	C (B series)	N (B series)	C/N (B series)
12	Green manure with purely cereal rotation	0·33	0·036	9·0	0·34	0·033	10·0
15	Effect of green manure and leguminous crop in rotation	0·34	0·041	8·3	0·38	0·039	9·8
16	As in 15 + Superphosphate at 80 lb P_2O_5	0·41	0·043	9·5	0·52	0·045	11·5
18	No manure	0·37	0·029	13·0	0·34	0·030	11·3

A comparison of the results given in Tables I and II indicates that there is a considerable improvement in the status of nitrogen and carbon by the application of farmyard manure to the soils of temperate and cool climates, whereas very slight or hardly any improvement is observed in this direction in warm and tropical regions under similar applications of organic manures.

Keen [1946] records similar observations in the Middle East under the same tropical conditions as in India. He has mentioned [*loc. cit.*, p. 48] another interesting difference in Cyprus from temperate climate conditions in the residual (second-year) manurial effect of organic material. Comparing various organic manures with artificial fertilizers on the same N, P, K basis, the increases in yield were the same. But the residual effect of artificials was found more in the larger yield of the next unmanured crop of wheat, a result which is contrary to what is recorded in temperate climates. The explanation suggested is that in the low rainfall area of Cyprus, loss of artificials by leaching does not take place, and the high temperature and dryness of the soil in summer cause the organic matter to decompose more than the nitrogen artificial. In some other places the nitrogen in the organics did not produce an increased yield. In Nigeria the effect on yield was traced to the phosphate content of the manure. Thus Keen is indeed of opinion that a good case could be made out for the peasants' custom,—so generally condemned—of using dung as a fuel. As a very small proportion of its nitrogenous value is obtained by plants as indicated by the above instances and as the potash and phosphorus value of the dung will remain even in its ash, the heat of oxidation by burning the dung might better be utilised for domestic purposes than losing it uselessly in the soil.

These striking observations need be tested in the light of experience under Indian conditions which are similar to the tropical conditions of the Middle East.

From a note prepared by the Imperial Bureau of Soil Science on 'Additions of Organic Matter to Tropical Soils' it is evident that the general conclusion from experiments on green manuring in hot countries like Rodhesia, Uganda and South Russia is that its value depends on the N, P, K content of the manure, and not very much on the organic matter. Results with tea in Assam [Carpenter, 1938], Malaya and elsewhere [Mann, 1935] have shown conclusively that ammonium sulphate is at least as efficient as an equivalent of organic manure in maintaining both quantity and quality of yield. Comparison of the residual effects of green manures with fallow showed that the effects were only significant in the first year after ploughing in. Green manures brought about a marked increase in the carbon and nitrogen of the soil, but the effects were transitory. Within a year of being ploughed in the plant residues decomposed so effectively that hardly any trace was left of them. Therefore, the data did not lend much support to the contention of building up of soil fertility by means of green manuring. On the other hand, that bulky organic manure like green manuring enhances yield in irrigated rice is probably a universal finding all over India. This is well recognised by the cultivators, but still it cannot be adopted as a universal practice due to the absence of necessary facilities. Cultivators often collect green leaves from near-by forests and apply them to the rice fields, where green manures cannot be conveniently grown. An application of 30 to 40 lb. of N in the form of green leaves can increase the yield of rice by 20 to 30 per cent. Heavy doses of 60 to 80 lb. of N have yielded even 100 per cent increase in certain centres.

Stewart [1947] considers the general picture emerging from experiments with bulky organic manures in India rather confused, as unlike concentrated artificial fertilizers which primarily supply plant food materials to the soil, bulky organic manures are complex and manifold in their action. They can simultaneously affect the chemical, physical and biological properties of the soil, and the experiments would be extremely complicated in design to accurately differentiate the individual changes brought about in the soil by the application of different organic manures. Because of the absence of analytical data for the materials used and the omission of any basis for the equivalent nutrients present in the different organic manures, it is difficult to assess the nutrient value of such materials under Indian conditions or explain apparently conflicting results from past experiments [Vaidyanathan, 1933 ; Rege, 1941 ; Sethi, 1943 ; and Panse, 1945].

Although conflicting results have been obtained from many experiments, the general conclusion arising from the bulk of evidence is that bulky organic manures play a very useful part in the maintenance of soil fertility and improvement of crop yields.

In an interesting series of trials on F.Y.M. at Dharwar where *jowar* was grown in rotation with cotton for several years in two sets of adjoining plots, the results obtained for seven years from 1932-33 to 1938-39 are given in Table III.

TABLE III

Trials on F.Y.M. with jowar *in rotation with cotton at Dharwar*

Treatment per acre	Response lb. per lb. N
Field manured every year at 25 lb. N	30·0
Do. for *jowar* 25	17·2
Do. Do. 50	18·5
Do. Do. 100	15·7
Do. Do. 150	11·9

These results show how the continuous use of F.Y.M. can increase productivity of *jowar*. Even when F.Y.M. was applied in alternate years, increased crop yields were maintained from applications up to 150 lb. N per acre.

A remarkable result at Dharwar indicated that response of *jowar* to oil cakes was increased considerably when applied on a basal dressing of F. Y.M. The results for four trials are given in Table IV.

TABLE IV

Response of jowar *to oil cakes with and without F.Y.M. at Dharwar*

Treatment	Response lb. per lb. N			
	Castor	Safflower	Cotton	Karanj
Cake at 20 lb. N per acre—				
Without basal F. Y. M.	4·9	4·5	1·5	5·2
With basal F. Y. M.	15·4	15·9	14·0	14·4

The manurial value of farmyard and similar organic manures depends on the degree of decomposition in the season of application. Undecomposed material may utilise soil moisture to aid its decomposition and also soil nitrogen in the absence of available nitrogen from applied manures, as bacteria responsible for the decomposition of organic matter in the soil need nitrogen and may thus adversely affect the life of the plant at a critical period of its growth. Such factors are therefore often responsible for variations in response to organic manures applied at different times. For instance, in some areas the application of F.Y.M. in August gives better results with wheat than either June or October application due to the less availability of soil moisture in the latter. Under these conditions, an average response of 6·2 lb. per lb. N. was observed to cattle dung at various centres in C. P. and of 4·9 lb. per lb. N to F.Y.M. at Powerkhera.

Oil cakes are more efficient sources of N than F.Y.M. or cattle dung. *Til* (Sesamum) cake gave a response of 7·8 lb. of wheat per lb. N in 14 trials,—13 at Tharsa and one at Adhartal, *karanj* (*Pungamia glabra*) cake gave 6·9 lb. in five trials at Chindwara and castor cake 11·8 lb. in 9 trials,—7 at Labhandi and 2 at Tharsa. In 7 trials at Labhandi, night soils and poudrette applied at 30 lb. of N per acre gave responses of 16·0 and 11·3 lb. of wheat per lb. N respectively.

In one trial at Indore the results obtained are given in Table V.

TABLE V

Effect of different organic manures and Am_2SO_4 on wheat at Indore

Treatment of N per acre	Yield of wheat lb. per acre			
	F. Y. M.	Compost	Night soil	Am_2SO_4
37 lb.	1422	1363	1345	1066
73 lb.	1526	1526	1807	1111
10 lb.	1532	1881	1837	1244

It is shown that at the high level of nitrogen applied, nitrogen from organic sources proved more effective than ammonium sulphate. Here, however, no account was taken of the contents of P and K contained in the organic manures, which might partly be responsible for producing higher yields with them.

It is rather difficult to assess the value of organic manures in single year or short-term experiments, and more detailed work of a long-term nature is needed. Norris [1923], while studying this aspect of the problem, discussed the results of 36 successive crops taken off the permanent manurial plots at Coimbatore that had been manured with cattle manure, or with ammonium sulphate, superphosphate and potassium sulphate singly and in different combinations. Comparing cattle manure with mineral manure, the average yields of crops manured separately with cattle manure and complete mineral manure expressed as per cent on 'No manure' are given in Table VI for two periods. The first covers 36 crops as dealt with by Norris [1923] and the second refers to the subsequent 20 crops dealt with by Viswanath [1931].

TABLE VI

The results of permanent manurial plots at Coimbatore

	No manure		Complete mineral manures		Cattle manure	
	Grain	Straw	Grain	Straw	Grain	Straw
From 1st to 36th crop—						
Cholam	100	100	292	191	295	192
Ragi	100	100	903	548	750	426
Wheat	100	100	246	230	171	191
From 37th to 56th crop—						
Cholam	100	100	336	165	384	202
Ragi	100	100	429	402	409	479
Ranivaragu	100	100	377	306	461	370
Wheat	100	100	237	201	356	290
Cambodia cotton *kapas*	100		133		191	

The effect of F.Y.M. on the first 36 crops was generally inferior to that of the complete mineral manure. The averages for the 37th to 56th crop were, with the exception of those for *ragi*, distintly in favour of F.Y.M. It may be stated here that for *ragi* it was only in the case of crop No. 38 that the yield from the mineral manure plot was higher than that from the F.Y.M. plot. If this crop is left out, the average for the rest of the crops from the F.Y.M. plots are greater than those from the mineral manure plots.

Thus, artificial fertilisers are somewhat superior to F.Y.M. in the earlier years of their application, but in later years the F.Y.M. asserts itself in contributing to greater yields over artificial fertilizers. This conclusion is supported by the results of experiments at Rothamsted. Russell [1926] in his Hitchcock lectures in America, drew attention to this fact.

Viswanath [1930] has shown that organic manures assist the assimilation of chemical fertilizers in the soils tested by him.

TABLE VII

Effect of Chemical fertilizers with and without organic manures

Pot cultures—Coimbatore

Treatments		*Yield* (relative merits taking green manure = 1)
Artificials	No manure	0·33
	P (superphosphate)	0·50
	N (ammonium sulphate)	0·70
	N+P (Am_2SO_4+Super)	0·90
Artificials with organic manures	Green manure	1·00
	G. M.+phosphate	1·20
	G.M.+nitrogen	1·33
	G.M.+N+P	1·60

Field experiments—Manganallur Experiment Station—Paddy

	lb. per acre
Green leaf at 3,500 lb. per acre	2,033
Green leaf at 3,500 lb. per acre+1 cwt. Am_2SO_4	2,433
Ammonium sulphate 1 cwt.	2,078
Control	1,658

Palur Experiment Station—Sugarcane

	Per cent increase in yield over standard
Cake N 50 lb.	Standard
Cake N 100 lb.	30·9
Cake N 80 lb.+mineral N 20 lb.	41·6
Cake N 60 lb.+mineral N 40 lb.	56·5
Cake N 40 lb+mineral N 60 lb.	38·2
Cake N 20 lb.+mineral N 80 lb.	49·6
Cake N *nil*+mineral N 100 lb.	40·5

Samalkot Experiment Station—Sugarcane

Plot size 2·4 cents	Weight of cane per plot in lb.	Weight of cane per acre in lb.
Castor cake (107 lb. N)	2,254	93,915
Castor cake+Am_2SO_4 (107 lb. N)	2,499	104,166

For the soils tested above, neither chemical fertilizers nor organic manures by themselves are adequate. It is only by the combination of both that the best results are obtained. The addition of fertilizers increases the assimilation of the nutrients in F.Y.M. and *vice versa*.

Hendry [1928] carried out comparative experiments on the relative merits of organic manures and artificial fertilizers spread over a number of years. He applied different manures and fertilizers for five consecutive years and then measured their residual effects during another period of five years. The results are stated in Table VIII. The percentage increases due to residual effect are the averages of five yearly increases.

TABLE VIII

Hmawbi Experiment Station, Burma—Paddy

Treatment per acre	Per cent increase over control (5 years)	Residual effect. Per cent increase over control during 5 years
Cattle manure at 30 lb. N	+37·5	+21·8
Cattle manure at 50 lb. N	+52·3	+34·5
Cattle manure at 70 lb. N	+68·7	+37·8
Cotton cake at 50 lb. N	+54·8	+29·2
Cattle manure at 30 lb. N+Super at 20 lb. P_2O_5	+43·6	+27·6
Cattle manure at 30 lb. N+Bonemeal at 20 lb. P_2O_5	+51·0	+31·8
Bonemeal at 20 lb. P_2O_5	+26·5	+9·5
Super at 20 lb. P_2O_5	+36·3	+15·3
K_2SO_4 at 20 lb. K_2O	+5·0	—6·6
$NaNO_3$ at 30 lb. N	—17·0	—35·5
Am_2SO_4 at 30 lb. N+Super at 20 lb. P_2O_5+K_2SO_4 at 20 lb. K_2O	+33·5	+17·5
Am_2SO_4 at 30 lb. N	+32·5	—25·5

It is evident that while organic manures whose direct effects were in general equal or more than those of inorganic fertilizers, the residual effects of organic manures were in general more pronounced than the inorganic fertilizers, the exception being bonemeal among organics. Among inorganic fertilizers, super has some residual effects, as some of the soluble P_2O_5 is fixed in the soil and part of the fixed P_2O_5 is rendered available to the succeeding crop. No residual effect is however observed in the case of sodium nitrate or ammonium sulphate. The results of long-continued experiments at Rothamsted and Woburn in England point to similar results [*cf.* Russell, 1937] as stated in Table IX.

TABLE IX

Figures for Rothamsted and Woburn Experiment Station

Yield per acre

	Wheat average of 71 seasons	Barley average of 70 seasons	Mangolds average of 45 seasons
	Bushels	Bushels	Bushels
Rothamsted—			
14 tons F. Y. M.	34	46	18
Complete artificials	31	41	18
Woburn—			
7 tons F. Y. M.	20·5	27·7	..
Complete artificials	18·4	18·7	..

At Pusa, permanent manurial plots were laid out in 1908-09 with 16 treatments, including organic manures, green manures and inorganic fertilizers. These treatments were continued for 22 years upto 1929-30, when certain modifications in the

manurial treatments and crop rotations were made, under which these manurial experiments are being continued to date. There are now 18 treatments. The results of these two periods for some of the plots are stated in Table X and XI for comparison. There are two series of these experiments with the same manurial treatments, but having different crop rotations. During this period of 1908-09 to 1929-30 maize yields related to 22 years and there were 11 crops of *arhar* and oats. Manures were applied to maize every year, while the *rabi* crops showed only the residual effect, if any. These results were previously discussed by Menon and Bose [1937] and also by Parr and Sen [1947].

TABLE X

Permanent Manurial Plots, Pusa

Average for 22 years from 1908-09 to 1929-30

Yield in lb. per acre

Plot No.	Treatment per acre	A. Series			B. Series		
		Maize	Arhar	Oats	Maize	Arhar	Oats
1	No manure	658	959	649	491	937	484
3	F. Y. M. to supply 20 lb. N. .	860	1,027	882	819	1,111	764
5	Rape cake to supply 20 lb. N as in F. Y. M. plot No. 3	939	929	656	785	869	576
10	Am_2SO_4 to supply N, K_2SO_4 to supply K_2O and Super to supply P_2O_5 as in F. Y. M. plot No. 3	977	740	948	974	802	787
12	Green manure in cereal rotation .	804	384	622	749	461	649
16	G.M.+Super to supply P_2O_5 as in F. Y. M. plot No. 3	1,338	813	1,367	1,286	615	1,602

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The composition of the F.Y.M. and rape cake applied varied from year to year and their contents of P_2O_5 and K_2O were not constant. The average P_2O_5 and K_2O in F.Y.M. analysed for 22 years are about 13 and 17 lb. respectively per acre for 20 lb. of N in F.Y.M. Similar figures for rape cake are about 8 lb. each of P_2O_5 and K_2O per acre for every 20 lb. of N in rape cake. Except in the case of *arhar*, lower yields have been obtained for maize and oats with F.Y.M. and rape cake than with complete mineral manures. Green manure when combined with superphosphate has generally produced the best yields.

Table XI

Permanent Manurial Experiments, Pusa

Average for 17 years from 1930-31 to 1946-47

Yields in lb. per acre

Plot No.	Treatment per acre	A. Series					B. Series				
		Maize	Peas	Barley	Wheat	Arhar	Maize	Barley	Wheat	Arhar	Peas
1	No manure	410	234	248	366	659	374	281	250	564	161
3	F. Y. M. at 8,000 lb. (=40 lb. N + 26 lb. P_2O_5 + 54 lb. K_2O)	1,098	585	936	892	954	1,102	857	920	1,108	488
4	F. Y. M. at 4,000 lb. + Rape cake at 20 lb. N (=40 lb. N + 21 lb. P_2O_5 + 35 lb. K_2O)	1,298	525	883	810	809	1,237	893	687	960	414
5	Rape cake at 40 lb. N (=40 lb. N + 15 lb. P_2O_5 + 15 lb. K_2O)	1,007	307	728	568	707	888	596	441	706	274
10	Am_2SO_4 at 40 lb. N + Super at 80 lb. P_2O_5 + K_2SO_4 at 50 lb. K_2O	769	493	1,069	765	858	682	1,160	687	1,049	422
15	Effect of green manure and leguminous crop in rotation	597	247	745	599	482	531	795	553	500	197
16	As in 15 with additional application of super at 80 lb. P_2O_5	797	590	2,063	1,504	878	696	1,707	1,295	1,057	705

From the average composition of F.Y.M. and rape cake the values for P_2O_5 and K_2O have been computed for comparison with the complete mineral manure plot. Except for slightly more of K_2O in the F.Y.M. plot No. 3, in all other cases of F.Y.M. and rape cake plots the contents of P_2O_5 and K_2O are lower than those in the complete manure plot. Notwithstanding this, except with barley and in the rape cake plot the crop performance in the former is generally much better than in the latter which cannot be justified on the NPK basis alone. Green manuring combined with superphosphate has produced excellent yields, especially in the case of barley, wheat and peas.

These results show that even on the NPK basis, F.Y.M. alone or combined with rape cake has generally given better outturns than the complete mineral manures. This is rather striking and may be attributed to the presence of organic matter in the former.

Similar results are noticed in the New Manurial Series of the Permanent Manurial Plots at Pusa laid out in 1932 with ten treatments of ten replications each in randomised blocks. There is a four year rotation with maize as the *kharif* crop every summer followed by oats, peas, wheat and gram year after year as the *rabi* crop. As in the interval of 1932 to 1947, there are only about four *rabi* crops of each variety, only the yield of maize grown every year is considered in Table XII.

TABLE XII

Permanent Manurial Experiments, Pusa
New Manurial Series

Average for 15 years from 1932-33 to 1946-47

Yield of maize in lb. per acre

No manure	F. Y. M. at 8000 lb.=40 lb. N+23 lb. P_2O_5+56 lb. K_2O	Rape cake at 40 lb. N per acre=40 lb. N+15 lb. P_2O_5+15 lb. K_2O	Am_2SO_4 at 40 lb. N+ Superphosphate at 80 lb. P_2O_5+K_2SO_4 at 50 lb. K_2O per acre
207	421	547	395

Critical difference at 1 per cent=89·9
Critical difference at 5 per cent=67·7

Here it is evident that the F.Y.M. plot and particularly the rape cake plot have given higher yields of maize than the complete mineral manures. Rape cake is more quick-acting than F.Y.M. which decomposes rather slowly in the soil, and has therefore produced much better results than the F.Y.M. On the other hand, F.Y.M. and rape cake plots both contain much less P_2O_5 than the complete manure plot, while F.Y.M. plot contains a little more of K_2O and the rape cake plot much less of K_2O than the complete manure plot. Notwithstanding this deficiency, the organic manure plots have produced better yields than what can be expected on NPK basis alone. The conclusion therefore emerges that this higher yield should be attributed to the beneficial action due to the presence of organic matter in them. With the introduction of organic matter, great biochemical and biological reactions set in the soil. The increased microbiological activity not only makes the N and P of the added materials available, but also increases the rate at which the soil N and soil P become available, thus raising the general status of soil fertility. The soil is able to supply to the growing crops not only what is put in the soil in the form of manures, but also a considerable portion of its reserve N, P and K which were formerly not available. Active soil organisms determined by insertion of slides and fixing the micro-organisms on them in the field indicate that good growth of crop is associated with a large number of active organisms. In the adjoining plots of poor growth the number of active organisms is very much low.

The yield data of A and B series of permanent manurial plots at Pusa have shown that the green manure combined with superphosphate generally produces favourable results compared with other treatments involving complete mineral manures or organic manures like F.Y.M. and rape cake. Das [1947, unpublished data] reports results from similar experiments in Table XIII.

TABLE XIII

Field Experiments at Pusa

Manurial value of Superphosphate and green manure (sunn hemp) *in Pusa calcareous soils*

Yield of oats grain in lb. per 1/30 acre plot

Green manure (sunn hemp) and superploughed in the monsoon: the land kept fallow in *kharif* and a *rabi* crop of oats taken

Plot No.	Treatment	1923-24	1924-25*	1925-26	1926-27	1927-28	1928-29	1929-30	Mean yield in lb. per plot	Per cent increase over control
1	Control	9·73	34·40	14·87	13·87	No experiment	29·77	14·37	16·52	..
2	Green manure	17·43	63·13	29·27	26·17		26·17	33·87	26·58	60·90
3	Superphosphate	20·27	51·33	26·70	17·43		17·43	11·30	18·63	12·77
4	G. M.+Superphosphate	22·07	71·33	41·07	30·80		33·37	40·53	33·57	103·21
	Standard error	3·93	..	..	..		..	..	..	..
	Critical difference at 1 per cent	12·01	..	..	..		..	..	..	..
	Critical difference at 5 per cent	8·56	..	..	..		..	..	..	..

* The results of the year 1924-25 were omitted for the purpose of the combined statistical analysis on account of exceptionally high yields, although the standard error and critical differences altered but little from those obtained by including these results.

The effect of green manuring in releasing added, but fixed P_2O_5 to the crop and thereby increasing the yield is evident.

One general conclusion that emerges from these experiments at Pusa and elsewhere is that if F.Y.M. or any other organic manure is applied well in advance to decompose almost completely at the time of sowing, besides the NPK value of organic manures, there are other beneficial effects accruing from their presence in the soil.

Hutchinson [1923] has shown by field experiments that the application of previously fermented green manure, sunn hemp (*Crotalaria juncea*) with superphosphate gives greater crop returns in calcareous Pusa soils than the same ploughed in along with super. The green manure combined with super, on the other hand, yields better crops than super alone.

TABLE XIV

The effect of Superphosphate alone and with green and fermented sunn hemp at Pusa

Plot No.	—	1918	1919	1920	Total *kharif*	Difference from control	1917-18	1918-19	1919-20	1920-21	Total	Difference from control
		Kharif					*Rabi*				*Rabi*	
	Treatment.	Green maize lb. per acre					Oat grain lb. per acre					
26.	Super only (3 cwt.) . .	20,196	15,810	11,170	47,176	+1,512	1,185	554	649	585	2,973	+86
32.	Super+green sann . .	20,960	13,387	11,416	45,763	+99	2,080	764	762	663	4,269	+1,382
22.	Super and fermented sann, 3 to 1 concentration	21,748	15,441	10 677	47,866	+2,202	1,977	1,131	907	577	4,592	+1,705
30.	Super and fermented sann, 6 to 1 concentration	29,501	19,301	16,837	65,639	+35,036	2,643	1,564	934	910	6,051	+3,106
24.	Control for No. 30 . .	14,176	9,199	7,228	30,603	..	1,049	636	737	523	2,945	..
27. 31.	Controls average . .	20,504	12,471	12,689	45,664	..	1,036	681	609	561	2,887	..

Although superphosphate alone has but little effect on the oat crop, the increase due to its action in conjunction with organic residues is considerable. Further, the latter increase rises in proportion to the amount of organic matter added to the soil, and in this combination, in which the superphosphate appears to supply a limiting factor otherwise in defect in Pusa soil, the great value of the concentration 6 to 1 dose of fermented sann-hemp becomes obvious.

It is conceivable that organic phosphorus complexes are formed by the combined action of phosphatic fertilizers with humic or organic acids resulting from the decaying organic matter in the soil, whether present *in situ* or added as organic manures. And it is quite probable that such organic phosphates are significantly related to the crop yield resulting from the combined application of phosphatic fertilizers and organic matter.

Das [1945], while indicating the possibility of this effect, has recently shown that such organic phosphates are formed on composting green manure with phosphatic fertilizers and can be isolated for studies in water-culture experiments as against inorganic phosphates (K_2HPO_4) present in Knopp's nutrient solution. These organic phosphates are soluble in water, neutral in reaction, and possess colloidal properties. They remain in a highly dispersed state in the soil and have been shown to be more available to plants by water-culture experiments than the inorganic phosphates of phosphatic fertilizers used in ordinary farm practice, which are generally insoluble or eventually become so on reacting with soil bases. The data in Table XV explain this effect.

TABLE XV

The growth of ragi seedlings in nutrient solutions having inorganic and organic phosphates in them separately

Weights in mg. of 12 *ragi* seedlings

No.	Nature of nutrient solutions	Initial	Final (after 5 weeks)	Difference	Per cent increase over control
1	Knopp's solution (control)	4·4	10·2	5·8	—
2	Knopp's solution devoid of P_2O_5+organic phosphates isolated from the compost of lucerne+mono-calcium phosphate	4·1	15·2	11·1	91·4
	Duplicate+ do.	4·3	15·5	11·2	93·1
3	do. +Organic phosphates isolated from the compost of lucerne+di-calcium phosphate	4·2	14·8	10·6	82·8
4	do. +Organic phosphates isolated from the compost of lucerne alone	4·3	14·5	10·2	76·0

With regard to the efficacy of organic phosphates derived from different sources it is found that the compost of lucerne and monocalcium phosphate is the best, next comes in order the compost of lucerne and dicalcium phosphate, and the last is the compost of lucerne alone. In actual field practice already reported it has been observed that the compost of green manure and superphosphate or both ploughed in together always give better crop yields than either super or green manure applied alone.

Discussion

The work of Spencer and Stewart [1934] lends support to the contention as to the better efficacy of organic phosphates in soil. They showed that phosphates in the organic form of the type formula $R(OH)_x (OPO_3 M_Y)_z$ escapes, to a marked degree, the fixation in soil which normally occurs to the phosphates applied in inorganic forms. They experimented with organic phosphates of the above type prepared in the laboratory, such as, calcium mono-orthophosphate of glycerol $C_3H_5 (OH)_2 . OPO_3 Ca$ and potassium sorbityl diorthophosphate $C_6H_8 (OH)_4 . (OPO_3K_2)_2$. A highly calcareous soil did permit little phosphorus in the filtrate when a solution of pure monocalcium phosphate was allowed to percolate through it, whereas, under the same conditions, much phosphorus passed through the soil when the above organic phosphates were used for percolation. Thus the permeation of phosphates in the organic form into deeper soil layers in the close environs of plant roots is assured. This is also supported by the theory put forward by Ramann [1911] and Comber [1922] which suggests a distinct possibility of plant roots absorbing phosphates direct, probably through contact with the soil colloids and also by the hypothesis of Greenhill [1930], according to which 'solid phase' feeding of phosphoric acid by the roots of crops is probable.

The importance of the phosphate manuring of legumes for increasing the yield and feeding quality of the leguminous crop as such and also for improving general soil fertility has been ably demonstrated by Parr and Bose [1944 and 1945]. It is also quite probable that the decaying organic matter combines not only with the phosphates of the phosphatic fertilizers applied to form organic phosphates as stated above, but can also easily react with the reserve insoluble phosphates in the soil to form organic phosphates which become available to the growing crops as demonstrated by Das [1945]. This additional advantage of reserve soil phosphates being available to plants due to their reaction with the decaying organic matter besides the latter's NPK nutrients, is absent in the case of complete mineral fertilizers which supply only the NPK contained in them. The majority of Indian soils being deficient in available phosphates, the above phenomenon accounts, in a large measure, for the higher crop-returns from the applications of organic manures than complete mineral manures, although both of them may be applied on the same NPK basis.

As a matter of fact, it has already been observed in the permanent manurial experiments with Pusa soils that F.Y.M. and rape cake having even lower contents of P_2O_5 than the treatment with complete mineral manures gave higher crop yields than the latter. This can be explained by the fact that reserve soil phosphates

react with the decaying organic matter of F.Y.M. and rape cake, forming organic phosphates which become available to the growing crops and thus supplement the lesser amounts of P_2O_5 present in the organic manures applied. It is quite possible that the reserve N and K of the soil also which were not formerly available might be rendered available to the plants like the reserve phosphates due to the application of organic matter to the soil. It has already been pointed out that the application of organic matter improves the microbiological activity of the soil. This in its train may bring about the above reactions resulting in the availability of the reserve N, P and K in the soil. Thus, the soil which receives organic manures is able to supply not only what is put in, but a considerable portion of its reserve of N, P and K which were formerly not available. This additional advantage accruing from the presence of sufficient organic matter in the soil, either present *in situ* or applied as organic manures, is reflected in the higher crop returns, when compared with the inorganic fertilizers applied even on the same NPK basis.

Summary and conclusions

Many experiments have been reported above to show that neither chemical fertilizers nor organic manures by themselves are adequate. It is only by the combination of both that the best results are usually obtained. The greatest returns are in general obtained with nitrogenous fertilizers, although the action of phosphates is considerable. The response to the application of potassic fertilizers is not appreciable. The addition of fertilizers increases the assimilation of nutrients in the organic manures such as, F.Y.M., oil cakes and green manures, etc. and *vice versa*.

Although it is true that the continuous application of heavy organic manures even for a number of years does not ultimately much raise the C and N status of the soil, their application does play an important role in the maintenance of soil fertility and the improvement of crop yields in tropical soils. For, during the growing period of crops, the organic matter functions in stimulating the microbial activity of the soil which brings about in its train other beneficial effects in the form of rendering available the reserve N, P and K in the soil which were formerly not available. By the time the growing crops reach the stage of harvest, the beneficial action of organic matter almost comes to an end at the high prevailing temperature of the tropics, which quickly decomposes the organic manures, even though heavily applied. The beneficial effect thus lasts usually for the growing period of crops. Hence there is the great necessity of annual applications of organic manures to maintain the soil fertility at a high level and also to conserve all available sources of organic manures in the country. While stressing the importance of organic manures for tropical soils, the value of mineral supplements is not minimised.

The general evidence to date indicates that organic manures and inorganic fertilizers are both useful and they should be regarded as complementary in their effects. Experience in India and elsewhere has demonstrated both the value of organic manures and the inadequacy of the amounts available for general agriculture. Even if no cowdung were used as fuel and if all available organic and other

waste materials likely to be of manurial value were conserved and returned to the land, the supply would still fall far short of demands to improve and maintain soil fertility at a high level of crop performance. It is therefore reasonable to take all possible steps to return to the land all organic waste materials of value and to provide for supplementing such materials with mineral and other fertilizers as are likely to play an important part in maintaining and improving soil fertility.

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DEVELOPMENT OF COTTON SEED AND LINT DURING THE SECOND PHASE OF BOLL MATURATION

By S. M. NAWAZ, Technological Assistant, Cotton Research Laboratory, Lyallpur

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(With eight text-figures)

WITH the initiation of the reproductive phase in the cotton plant, fruiting parts become the centre of great metabolic activity and very rapid physio-chemical changes take place in the developing boll. The development of the fibre begins before fertilization by the elongation of the epidermal cells of the ovules. Similarly the ovules also begin increasing in size and the development of their internal tissues is initiated before fertilization has taken place. A very high percentage of the flowers is, however, subsequently shed as young bolls. The maturation period of bolls, apart from being a varietal character, is greatly influenced by the environment, and during practically the whole of this period the lint hairs are growing and developing.

Balls [1915] was the first to study the development of the cotton boll of an Egyptian variety of cotton (Strain No. 77) grown at Giza. He observed that the developing boll attained its full size in the first half of its maturation period. The seeds grew rapidly up to the 18th day after flowering. He also found that the development of the lint hairs took place in two distinct phases. The first half of the boll maturation period, being occupied by the lengthening of the primary wall of the hair, is followed, in the second half. by cellulose deposition in the form of daily concentric rings on the inner surface of the cell wall. The cotton fibre was, thus, shown to increase only in length during the first half, and only in strength and maturity during the second half of the boll maturation period.

A few other workers have also dealt with this aspect of the problem. Hock, Ramsay and Harris [1941], during their study on the microscopic structure of the cotton fibre observed that the percentage of cellulose in a series of cotton samples of different ages, increased rapidly with the age of the boll till about the 35th day after flowering. This observation was made on two varieties of *hirsutum* cotton, namely Missdel-7 and Mexican Big Boll, grown at the Delta Experiments Station, Stonewill. Iyengar [1943], while studying the variation in fibre properties of a number of pure strains evolved from Cambodia cotton *G. hirsutum*, grown in different places in Madras, found that the rate of wall thickening was more or less constant at Coimbatore, while it decreased appreciably with the age of the boll at Srivilliputhur.

These findings have thrown open a very wide field of research into the development of cotton fibre, but so far as the writer is aware, growth changes in various seed and lint characteristics, during the second phase of boll maturation have not been studied in great details so far. In order, therefore, to fill up this gap in the

present knowledge, studies were undertaken in 1942 at the Cotton Research Station, Mirpurkhas—Sind and the growth changes in seed weight, lint index, fibre weight per unit length and maturity counts were studied in detail.

Material and method

Two strains of *hirsutum* cotton namely M-4 and Sind Sudhar (S.S.), extensively grown in Sind at present, were studied for three consecutive seasons, 1942, 1943 and 1944. In a 'bulk plot' of each variety some 4,000 flowers were tagged on one day during profuse flowering. On the 18th day after flowering 20 to 30 developing bolls were collected at random. These were gently cut open and the locks were fixed immediately in the following solution.

Picric acid	1 gm.
70 per cent alcohol	75 c.c.
Formalin	25 c.c.
Glacial acetic acid	5 c.c.

The material was kept in this solution for 48 hours and was then thoroughly washed with methylated spirit. It was then dried in the sun. Such random samples of bolls were regularly drawn and fixed as above on alternate days till the 36th day after flowering.

The details of sampling dates for different seasons and varieties are set out in Table I.

TABLE I

Sampling dates

Seasons	1942		1943		1944	
	M-4	S.S.	M-4	S.S.	M-4	S.S.
Date of tagging of flowers .	1-8-42	29-8-42	10-8-43	31-8-43	25-8-44	11-9-44
Date of first sampling . .	20-8-42	15-9-42	27-8-43	17-9-43	11-9-44	28-9-44
Date of last sampling (10th)	5-9-42	3-10-42	14-9-43	5-10-43	29-9-44	16-10-44

The seed-cotton obtained from each sample was thoroughly mixed and a random sample of 200 seeds with lint on, was taken out for making various determinations. The lint was later carefully separated from seeds by hand.

The following features were studied for each sample :

1. Seed weight per 100 seeds.
2. Lint Index (weight of lint on 100 seeds).
3. Ginning percentage.
4. Mean fibre length in inches.
5. Mean fibre weight per unit length (whole fibre).
6. Mean fibre weight per unit length of middle section.
7. Maturity counts.

The mean fibre length was determined by means of the Attachment to the Stapling Apparatus designed by Ahmad and Nanjundyya [1938]. The mean fibre weight was found by weighing five tufts, each of about 400 whole fibres, on the torsion balance, and then expressing the mean result as weight per unit length. The mean fibre weight per unit length of middle section was determined by cutting a known length of the middle section by means of the Stapling Apparatus [1936]. After counting the number of fibres in that section, the tuft was weighed on the torsion balance. The unit fibre weight, calculated from the weight of the bunch and the number of fibres it contained, was converted into mean fibre weight per unit length. The maturity of the fibres was determined with the help of Gulati and Ahmad's [1936] maturity slide.

Experimental results

The experimental data are given in Tables XVII to XXIII in the Appendix. It will be convenient to discuss these under two sub heads, namely (a) Growth of seed and lint, and (b) developmental changes in fibre properties.

(a) *Growth of seed and lint*

The actual data pertaining to seed weight, lint index and ginning percentage are given in Tables XVII to XIX in the Appendix.

In order to remove the discrepancies, introduced by uncontrollable factors, in the development of seed and lint, growth curves of the logistic type were fitted to the observed values of seed weight and lint index for each cotton and for each season separately. The method of fitting the curves is given below in detail [Mills, 1938].

The equation to a logistic curve is $1/y = a + bc^x$, where y is the property under discussion and a, b and c are the constants. Reciprocals of y are determined and multiplied by suitable numbers to get rid of the decimals. The chronologically arranged data are then divided into three equal groups, *n* being the number of observations in each group, and S_1, S_2 and S_3 the total of the three groups. Then

$$d_1 = S_2 - S_1 \text{ and } d_2 = S_3 - S_2 \text{ and } C^3 = d_2/d_1$$

$$b = \frac{d_1\,(c-1)}{(C^n-1)^2} \text{ ; and } a = 1/n \left[S_1 - \frac{d_1}{(c^n-1)} \right]$$

Where x is the number of intervals in the growth period, each interval in the present case is of two days.

Illustration

Period	Y = Lint index	1/y × 100,000	
20	1·30	76923	
22	2·16	46296	S_1 = 161242
24	2·63	38023	
26	2·73	36630	
28	3·26	30675	S_2 = 94929
30	3·62	27624	
32	3·92	25510	
34	3·91	25575	S_3 = 75655
36	4·07	24570	

$$d_1 = -66313 = S_2 - S_1 \qquad C^3 = \frac{-19274}{-66313} = +\,0{\cdot}29065$$

$$d_2 = -19274 = S_3 - S_2 \qquad C = 0{\cdot}66220$$

$$b = \frac{-66313 \times -3378}{(-0{\cdot}70935)^2}$$

$$= 22400{\cdot}53/0{\cdot}503177$$

$$= 44518$$

$$a = \tfrac{1}{3}\left(161242 - \frac{-66313}{-0{\cdot}70935}\right)$$

$$= 22586$$

To obtain the calculated values of y, the equation was worked out for each observation of the above illustration. The observed as well as the calculated values are given below :

Period in days	Observed	Calculated
20	1·30	1·490
22	2·16	1·921
24	2·63	2·375
26	2·73	2·815
28	3·26	3·211
30	3·62	3·539
32	3·92	3·796
34	3·91	3·989
36	4·07	4·127

In order to see if there were varietal difference in the mode of development of seed and lint of both the cottons, the mean values of all seasons for each variety were worked out and curves were fitted to the data as shown in Figs. 1 and 2.

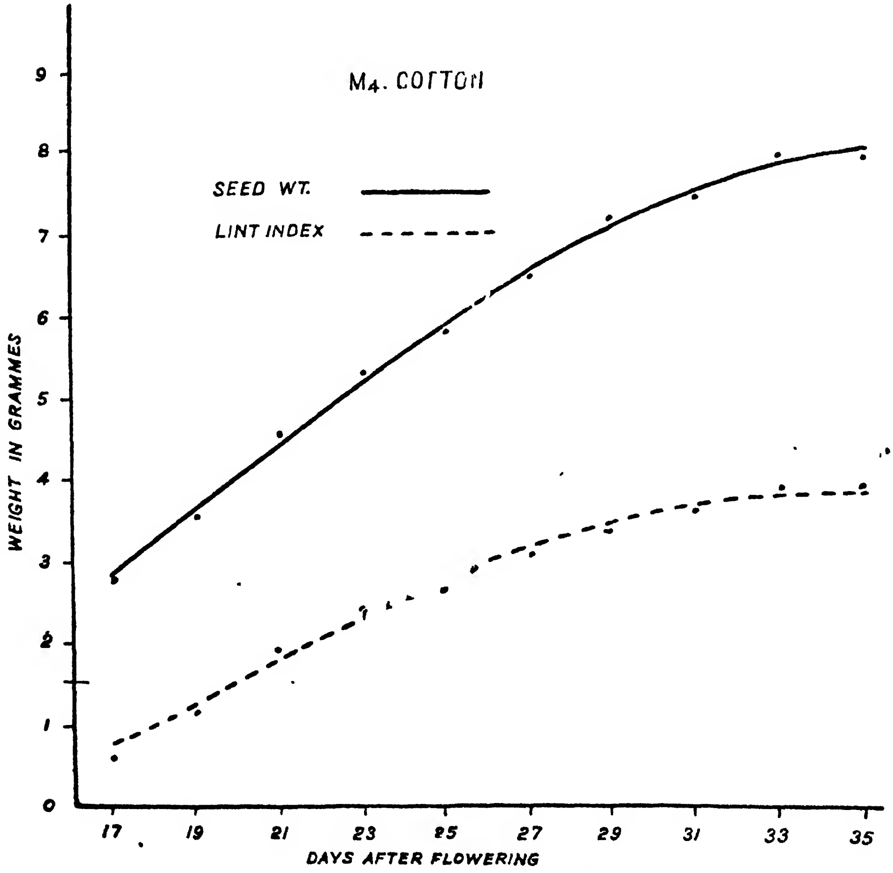

FIG. 1. Growth of seed weight and lint index (observed and calculated)

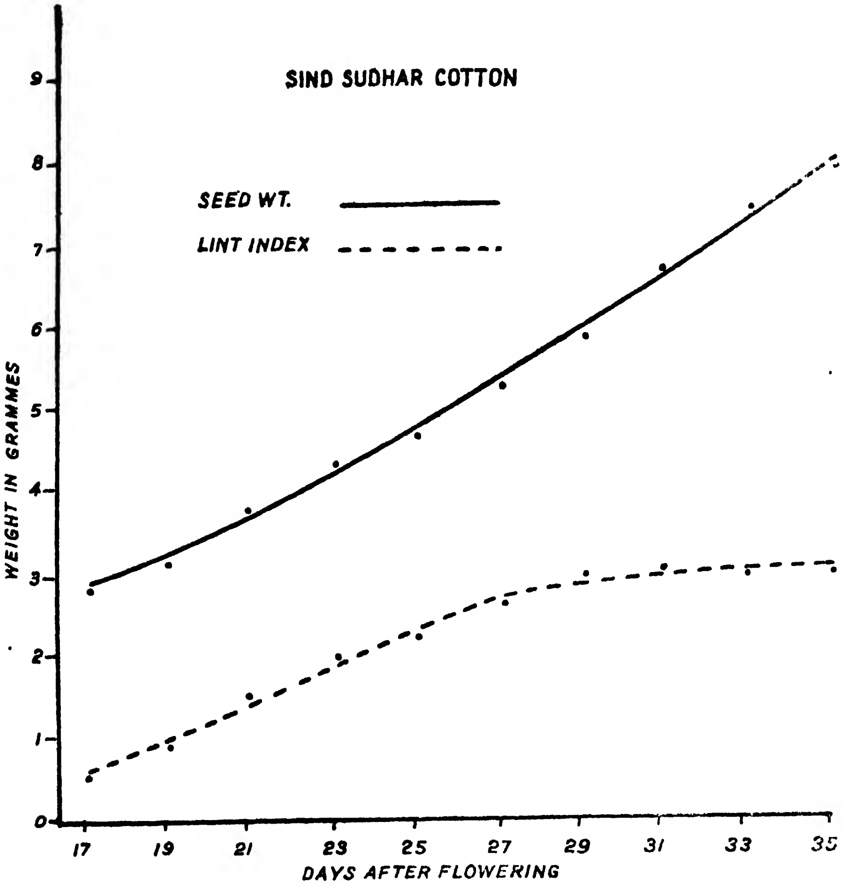

FIG. 2. Growth of seed weight and lint index (observed and calculated)

It is interesting to note from these figures that the curves for seed weight and lint index manifest a divergence from each other with the age of the boll. In the case of Sind Sudhar, the two curves run parallel for about a week, and then divert from each other. In the case of M-4, on the other hand, there is a steady increase in the angle of two curves from the very beginning of second phase of boll development. It will, however, be noticed that in the case of M-4, the curve of the seed weight showed a depression in its angular trend a few days before the boll finished its life cycle, showing thereby the lag in the rate of development of M-4 as compared to Sind Sudhar.

In view of such differences in the rate of growth of lint and seed in these two cottons, it was felt necessary to study the differential changes in seed weight and lint index by working out the relative rate of growth of each property with the help of the following formula.

$$\text{Relative rate of growth} = \frac{1}{w}\frac{dw}{dt} = \frac{\log_e w_2 - \log_e w_1}{t_2 - t_1}$$
$$\doteq \tfrac{1}{2}(\log_e w_2 - \log_e w_1)$$

Where W_1 and W_2 are the weights of seed or lint on two successive days in the age of the boll. The values of relative rate of change of lint index and seed weight and their ratios are given in Table II and Table III for each cotton separately.

TABLE II

M-4 : Relative rate of growth of seed weight and lint index and their ratios

Age of bolls in days	1942			1934			1944		
	Lint index	Seed weight	Ratio	Lint index	Seed weight	Ratio	Lint index	Seed weight	Ratio
18	..	..	..	·1850	·1061	1·743	·2023	·0955	2·118
20	·1268	·0757	1·674	·1515	·0927	1·634	·1676	·0867	1·933
22	·1074	·0718	1·496	·1158	·0782	1·481	·1330	·0772	1·722
24	·0848	·0654	1·297	·0824	·0644	1·281	·0940	·0669	1·405
26	·0648	·0609	*1·063*	·0554	·0515	*1·076*	·0668	·0564	*1·184*
28	·0489	·0550	0·890	·0354	·0404	0·878	·0440	·0467	0·942
30	·0354	·0502	0·706	·0218	·0308	0·705	·0278	·0383	0·725
32	·0240	·0444	0·549	·0132	·0230	0·575	·0157	·0314	0·500
34	·0160	·0392	0·410	·0079	·0161	0·492	·0092	·0243	0·379

TABLE III

Sind Sudhar : Relative rate of growth of seed weight and lint index and their ratios

Age of bolls in days	1942			1943			1944		
	Lint index	Seed weight	Ratio	Lint index	Seed weight	Ratio	Lint index	Seed weight	Ratio
18	·2329	·0656	3·546	·1960	·0645	3·039	·2526	·0644	3·922
20	·1956	·0648	3·016	·1669	·0648	2·577	·1534	·0595	2·578
22	·1563	·0634	2·466	·1373	·0607	2·262	·1197	·0563	2·126
24	·1168	·0626	1·866	·1056	·0601	1·757	·0903	·0526	1·717
26	·0806	·0603	*1·337*	·0770	·0581	*1·326*	·0639	·0476	*1·342*
28	·0505	·0588	0·860	·0516	·0552	0·935	·0418	·0442	0·945
30	·0310	·0570	0·455	·0341	·0533	0·639	·0276	·0392	0·704
32	·0192	·0554	0·345	·0229	·0501	0·447	·0136	·0349	0·390
34	·0100	·0533	0·188	·0135	·0478	0·282	·0106	·0307	0·345

The relative rate of growth of both the characters for each variety is shown in Figs. 3 and 4. An examination of Tables II and III and the relevant graphs would show that the relative rate of growth of lint index for both the varieties was markedly higher than that of the seed weight in the beginning of the second phase of boll maturation. With the advance in the age of the boll, both the growth rates manifested a gradual fall which was much steeper in the case of lint index than of the seed weight. This resulted in narrowing down the initial differences between the two rates and ultimately on or about the 27th day after flowering both the curves converged to a point. The relative rate of growth of lint index and seed weight became almost similar on that date, and thereafter reversed their positions with increasing difference till the day of boll opening. This phenomenon was manifested in all the three seasons for both the cottons at about the same age of the boll.

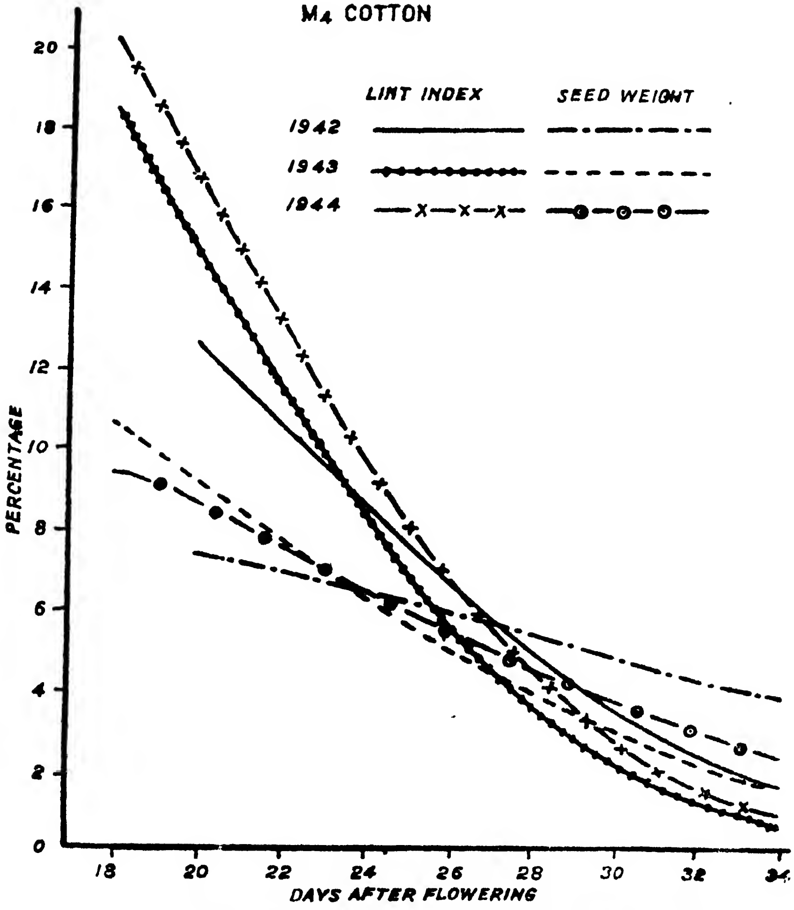

FIG. 3.—Relative rate of growth of lint index and seed weight

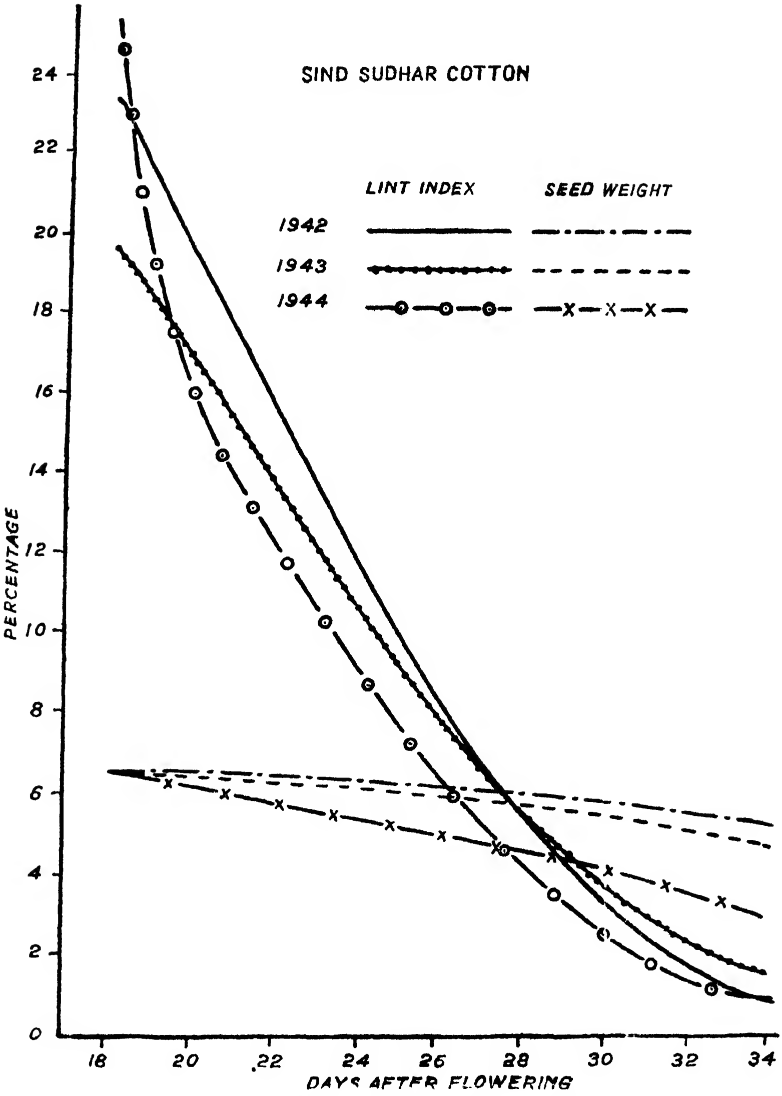

FIG. 4.—Relative rate of growth of lint index and seed weight

It is, however, interesting that the angle of convergence of curves for seed weight and lint index is bigger in the case of Sind Sudhar than that of M-4. A reference to Tables II and III would reveal that Sind Sudhar exhibited invariably a lower relative rate of growth of seed weight than M-4 in the beginning of the second phase of boll maturation, but with the advance in age this difference narrowed down systematically till about the 27th day, when it became zero, after which Sind Sudhar grew in seed weight comparatively more than M-4. In the case of lint index, Sind Sudhar had usually a higher rate of growth than M-4 all through the period of development, barring a few exceptions just at the tail end of its growing period. This explains the difference in the angle of convergence of curves in both the varieties.

Ginning percentage

After fitting the growth curves the ginning percentages were worked out from the calculated values of seed weight and lint index. These values are given in Table IV.

TABLE IV

Ginning percentage

Age of bolls in days	M-4			Sind Sudhar		
	1942	1943	1944	1942	1943	1944
17	..	26·0	21·4	17·2	19·7	20·0
19	28·6	29·2	25·1	22·4	24·2	23·9
21	30·6	31·7	28·3	27·3	28·2	27·5
23	32·2	33·4	30·5	31·1	31·4	30·1
25	33·6	34·2	31·8	33·5	33·4	31·7
27	33·2	34·4	32·2	34·4	34·2	32·4
29	33·0	34·2	32·1	34·1	34·1	32·3
31	32·4	33·6	31·6	32·9	33·2	31·9
33	31·5	33·3	31·0	31·3	32·0	31·1
35	30·5	32·9	30·3	29·5	30·5	30·3

The data in the above Table as well as in Table XIX of the Appendix, show that there was a gradual increase in ginning percentage with the age of the boll, attaining its maximum value by about the 27th day after flowering, when the curves of relative rate of growth of lint index and seed weight intersected each other and thereafter there was a gradual fall on account of higher relative rate of growth of seed till the boll matured. Thus the ginning percentage of the *kapas* in a fully matured boll is about 2 to 4 percent less than what it was a week before the opening of the boll. The highest values occurring in the Table IV have been under lined.

From the trend of rise and fall of ginning percentage it would be again noticed that though Sind Sudhar manifested an appreciable lag in ginning percentage in the beginning, it touched its maximum at practically the same time as M-4 did, but it, eventually, lost its superiority in ginning outturn to M-4 because of higher rate of development of seed in the later stages. Taking the mean of three seasons, while M-4 experienced a loss of 2·2 per cent in ginning outturn, Sind Sudhar exceeded this figure by 1·4 per cent.

(b) *Developmental changes in fibre properties*

The actual data pertaining to the different fibre properties are given in Table XX to XXIII.

Mean fibre length

The values of mean fibre length were examined statistically by the method of analysis of variance, primarily to isolate the variance due to age. The analysis of variance is given in Table V showing the contribution of variance due to various factors and their significance.

TABLE V

Analysis of variance of mean fibre length

Due to	D F	S. S.	M. S.	Ratio	Significance
Cottons	1	·006229	·006229	15·418	**
Years	2	·008711	·004356	10·782	**
Ages	8	·025000	·003125	7·735	**
First order inter-actions—					
Cottons × years . . .	2	·003971	001986	4·915	*
Cottons × ages . . .	8	·004838	·000605	1·498	N.S.
Years × ages . . .	16	·005989	·000731	..	.
Error	16	·006462	·000404	..	..
Total .	53	·061200	..	..	..

** Significant at P = ·01
* Significant at P = ·05

It will be seen from Table V that contrary to general expectation, the mean fibre length exhibited some variability with age even during the second phase of boll development. In order to see if this variability was in any way due to high sampling error or otherwise, the variance due to ages was further split up into linear and quadratic components by fitting polynomials to the mean values of three seasons for each cotton. The procedure followed for fitting the polynomials was the sum and difference method given by Fisher [1925].

The contribution of each component is shown in Table VI.

TABLE VI

Analysis of variance of mean fibre length due to ages

Polynomial term	D.F.	M-4			Sind Sudhar		
		S. S.	M. S	Ratio	S. S.	M. S.	Ratio
Linear	1	·003672	·003672	11·208*	·013260	·013260	22·211**
Quadratic	1	·001173	·001173	3·580	·006282	·006282	10·524*
Error	6	001965	·000327	.	·003582	000597	..
Total	8	·006810	..	..	·023124	..	..

It is clear from Table VI that most of the variance due to ages is contributed by the linear component in the case of M-4 and both linear and quadratic components in the case of Sind Sudhar. Thus, there is a strong evidence that the lengthening phase of both the cottons had not ceased by the 19th day of their age, which is just the first half of boll maturation period. Thus Ball's [1915] inference from his study on Strain 77, (*G. barbadense*), that the lengthening phase finishes by the first half of maturation period of a boll, is not corroborated by the above study. The fact is that there was a significant increase in the mean fibre length of both the varieties from 19th to 25th day. This increase was more pronounced in the case of Sind Sudhar, which exhibited a parabolic rise in this period. This explains. also, the higher relative rate of growth of the lint index of Sind Sudhar in the beginning of the second phase of boll development.

During this period, when elongation of fibres was still taking place, the cellulose deposition had started simultaneously as would be clear in the further analysis of other fibre properties. This supports the view of Gulati and Ahmad [1945] who suggested that the two phases of development overlap to some extent.

It is interesting to note the difference in the elongation period of two cottons. While both of them matured practically in the same period, M-4 took a lead over Sind Sudhar in completing its first phase a few days earlier than the latter. This shows a difference in the rate of lengthening, which was greater for M-4 than for Sind Sudhar.

Mean fibre weight per unit length

Logistic curves were fitted to the values of mean fibre weight per unit length of the whole fibre and of middle section. The procedure adopted was the same as explained in the case of seed characters.

The calculated values of mean fibre weight per unit length of whole fibre and of middle section for both the cottons are given in Tables VII and VIII.

TABLE VII

M-4 : Mean fibre weight per unit length in 10^{-6} oz. (calculated)

Age of boll in days	1942		1943		1944	
	Whole fibre	Middle section	Whole fibre	Middle section	Whole fibre	Middle section
19	·0669	·0703	·0618	·0639	·0490	·0481
21	·0810	·0854	·0808	·0861	·0746	·0751
23	·0957	·1011	·1023	·1090	·1000	·1027
25	·1105	·1169	·1211	·1300	·1197	·1245
27	·1246	·1318	·1366	·1473	·1324	·1386
29	·1374	·1454	·1483	·1601	·1395	·1466
31	·1485	·1572	·1567	·1691	·1433	·1507
33	·1580	·1671	·1624	·1750	·1453	·1528
35	·1657	·1751	·1661	·1789	·1461	·1538

TABLE VIII

Sind Sudhar : Mean fibre weight per unit length in 10^{-6} oz. (calculated)

Age of boll in days	1942		1943		1944	
	Whole fibre	Middle section	Whole fibre	Middle section	Whole fibre	Middle section
19	·0443	·0434	·0458	·0454	·0444	·0440
21	·0619	·0616	·0625	·0632	·0586	·0587
23	·0813	·0823	·0808	·0830	·0740	·0748
25	·1000	·1031	·0988	·1027	·0895	·0909
27	·1160	·1215	·1147	·1201	·1037	·1055
29	·1283	·1362	·1275	·1340	·1157	·1177
31	·1370	·1467	·1371	·1442	·1252	·1272
33	·1428	·1539	·1438	·1512	·1323	·1341
35	·1465	·1586	·1484	·1558	·1374	·1390

It will be noticed from the above Tables that the rise in mean fibre weight per unit length was very pronounced in the beginning of the second phase of boll maturation. The mean fibre weight per unit length of middle section was higher than that of unit length of the whole fibre all through the process of cellulose deposition. Ahmad [1942] had also found that the weight of the middle section of the collapsed mature hair is higher than that of the whole fibre. It is interesting to note that the difference between the fibre weight of whole fibre and of middle section increased systematically with the advance in the age of the boll. The following Table shows the respective differences for both the cottons.

TABLE IX

Difference between mean fibre weight per unit length of middle section and whole fibre in 10^{-6} oz. at different ages of boll (raw data)

Age of boll in days	M-4			Sind Sudhar		
	1942	1943	1944	1942	1943	1944
19	+·002	+·002	—·002	—·003	·000	—·001
21	+·007	+·005	+·004	+·005	·000	+·000
23	+·005	+·006	+·001	+·000	+·002	+·001
25	+·008	+·010	+·005	+·003	+·005	+·002
27	+·006	+·011	+·007	+·005	+·002	—·001
29	+·007	+·009	+·006	+·009	+·007	+·003
31	+·011	+·012	+·005	+·009	+·006	+·001
33	+·008	+·011	+·008	+·011	+·009	+·002
35	+·008	+·017	+·010	+·013	+·007	+·002

In order to see if these differences were significant, the above data were analyzed for different sources of variance, and the analysis is given in Table X.

TABLE X

Analysis of variance of difference between mean fibre weight per unit length (middle section and whole fibre)

Due to	D. F.	S. S.	M. S.	Ratio	Significance
Cottons	1	·00015000	·00015000	23·9	**
Seasons	2	·00015544	·00007772	12·4	**
Ages	8	·00045166	·00005646	9·1	**
1st order inter-action—					
Cottons × seasons	2	·00003611	·00001806	2·89	..
Cottons × ages	8	·00002967	·00000371	0·6	N.S.
Seasons × ages	16	·00005090	·00000318	0·5	N.S.
Error	16	·00010022	·00000626	..	..
Total	53	·00097400	..	..	..

In order to see if the trend of the increase in the differences was recti-linear or curvi-linear, the sum of squares due to ages was further split up into various factors and the analysis is given below :

TABLE XI

Splitting of sum of squares into various terms

Term	D. F.	S. S.	M. S.	Ratio
Linear	1	·00041387	·00041387	555·5**
Quadratic	1	·00003301	·00003301	44·3*
Error	6	·00000477	·00000079	..
Total	8	·00045165	..	..

It is clear from the above analysis that not only did the difference increase with the age of the boll, but that there was a parabolic rise in the beginning of the second phase, showing a higher rate of deposition in that period. This point has further been substantiated in greater detail on working out the relative rate of increase of mean fibre weight per unit length of middle section and of whole fibre. The relevant values for both the varieties are given in the following Tables :

TABLE XII

M-4 : Relative rate of increase of mean fibre weight per unit length

Age of boll in days	1942		1943		1944	
	Whole fibre	Middle section	Whole fibre	Middle section	Whole fibre	Middle section
20	·09561	·09728	·13403	·14909	·21016	·22276
22	·08338	·08436	·11796	·11793	·14651	·15649
24	·07185	·07258	·08436	·08808	·08996	·09627
26	·06013	·05998*	·06020	·06247	·05036	·05364
28	·04885	·04911	·04110	·04166	·02614	·02802
30	·03885	·03903	·02753	·02736*	·01342	·01376
32	·03100	·03054*	·01788	·01714	·00690	·00695
34	·02376	·02338*	·01127	·01103	·00309	·00328

TABLE XIII

Sind Sudhar : Relative rate of increase of mean fibre weight per unit length

Age of boll in days	1942		1943		1944	
	Whole fibre	Middle section	Whole fibre	Middle section	Whole fibre	Middle section
20	·16727	·17509	·15544	·16539	·13875	·14413
22	·13631	·14486	·12840	·13626	·11666	·12118
24	·10351	·11266	·10056	·10648	·09508	·09746
26	·07421	·08208	·07460	·07825	·07367	·07443
28	·05039	·05711	·05284	·05486	·05466	·05477
30	·03280	·03712	·03631	·03669	·03948	·03879*
32	·02073	·02399	·02388	·02369*	·02758	·02642*
34	·01276	·01504	·01573	·01496*	·01892	·01794

The above Tables and the graphic representation in Figs. 5 and 6 clearly show that the middle section of the fibre was not only heavier than the whole fibre all through the process of cellulose deposition but even the relative rate of increase of middle section was greater than that of the whole fibre during different stages of the second phase of boll maturation except in a few cases marked by asteriks in these Tables.

The initial higher rate of development in Sind Sudhar as compared to M-4 has also been manifested in the corresponding values of fibre weight. On the average, Sind Sudhar showed a tendency to grow at a higher rate than M-4.

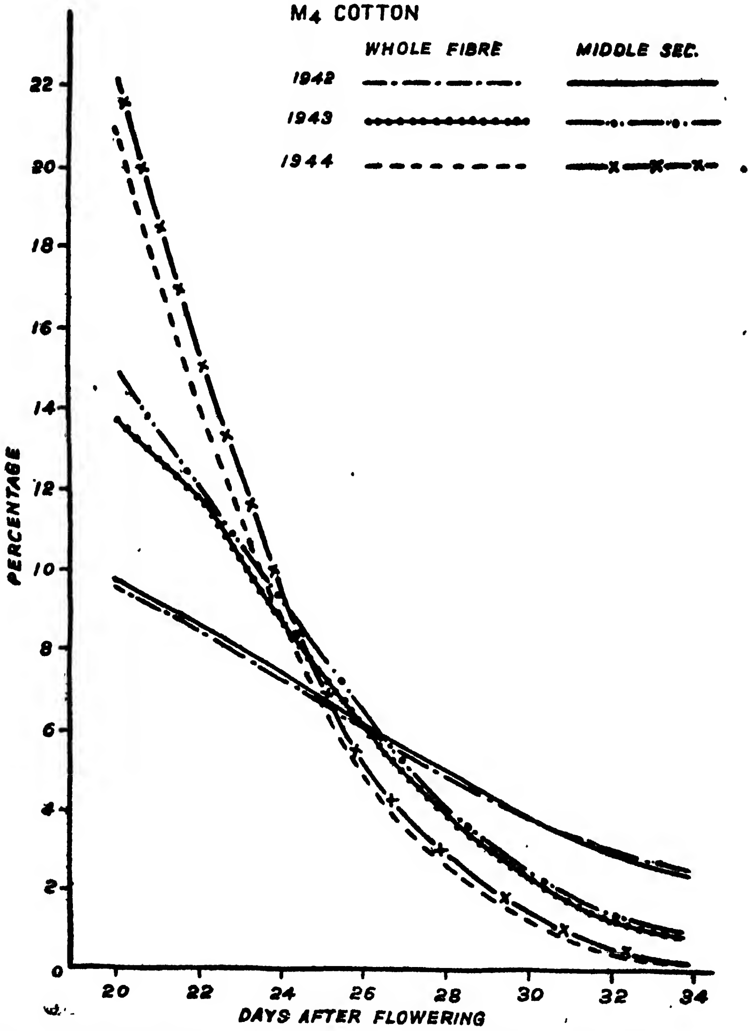

FIG. 5. Relative rate of increase of fibre weight (whole fibre and middle section)

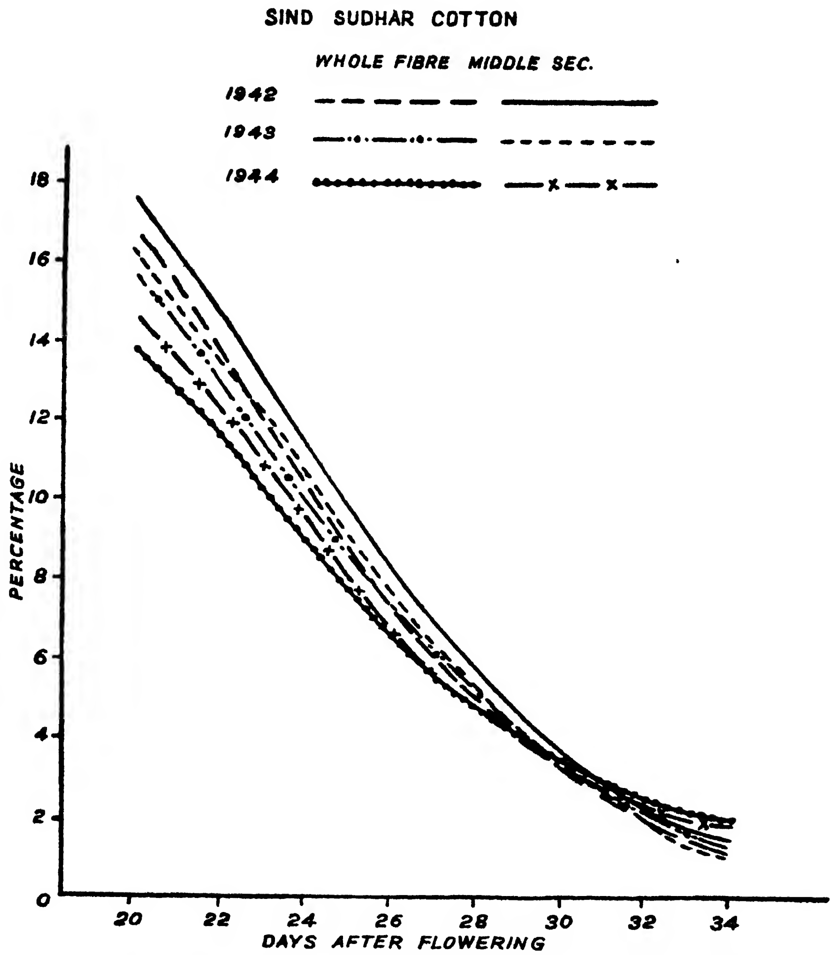

FIG. 6. Relative rate of increase of fibre weight (whole fibre and middle section)

An examination of the above Tables reveals that the seasonal changes are large in M-4 but quite small in Sind Sudhar. For the former cotton the value on the 20th day is about four times as great as the value on the 34th day in 1942, 12 times in 1943 and 70 times in 1944. It is almost constant for Sind Sudhar for which the relative rate of increase on the 20th day is about 12 times that on the 34th day in all three seasons.

On comparing the values of the relative rate of growth of lint index (Tables II and III) and the relative rate of increase of mean fibre weight per unit length of the whole fibre (Tables XII and XIII), it will be observed that the corresponding values of both the characters for different ages lie very near each other except in

the very initial stages. It may thus be inferred that the increase in lint index was mostly due to the increase in cellulose deposition in the fibre, barring a few days in the beginning when the contribution to the lint index had been made by an appreciable increase in length. The values of relative rate of growth of lint index and fibre weight per unit length are given in Tables XIV and XV.

TABLE XIV

M—4 : Relative rate of growth of lint index and mean fibre weight per unit length (whole fibre)

Age of boll in days	1942		1943		1944	
	Lint index	Fibre weight	Lint index	Fibre weight	Lint index	Fibre weight
20	·1268	·09561	·1515	·13403	·1676	·21016
22	·1074	·08338	·1158	·11796	·1330	·14651
24	·0848	·07185	·0824	·08436	·0940	·08996
26	·0648	·06013	·0554	·06020	·0668	·05036
28	·0489	·04885	·0345	·04110	·0440	·02614
30	·0354	·03885	·0218	·02753	·0278	·01342
32	·0240	·03100	·0132	·01788	·0157	·00690
34	·0160	·02376	·0079	·01127	·0092	·00309

TABLE XV

Sind Sudhar : Relative rate of growth of lint index and mean fibre weight per unit length (whole fibre)

Age of boll in days	1942		1943		1944	
	Lint index	Fibre weight	Lint index	Fibre weight	Lint index	Fibre weight
20	·1956	·16727	·1669	·15544	·1534	·13875
22	·1563	·13631	·1373	·12840	·1197	·11666
24	·1168	·10351	·1056	·10056	·0903	·09508
26	·0806	·07421	·0770	·07460	·0639	·07367
28	·0505	·05039	·0516	·05284	·0418	·05466
30	·0310	·03280	·0341	·03631	·0276	·03948
32	·0192	·02073	·0229	·02388	·0136	·02758
34	·0100	·01276	·0135	·01573	·0106	·01892

The values of the relative rate of growth of lint index and increase of fibre weight have been also shown in Figs. 7 and 8. Examination of above Tables and the relevant graphs shows that except in the initial stages of the second phase the values of both the characters are very close to each other.

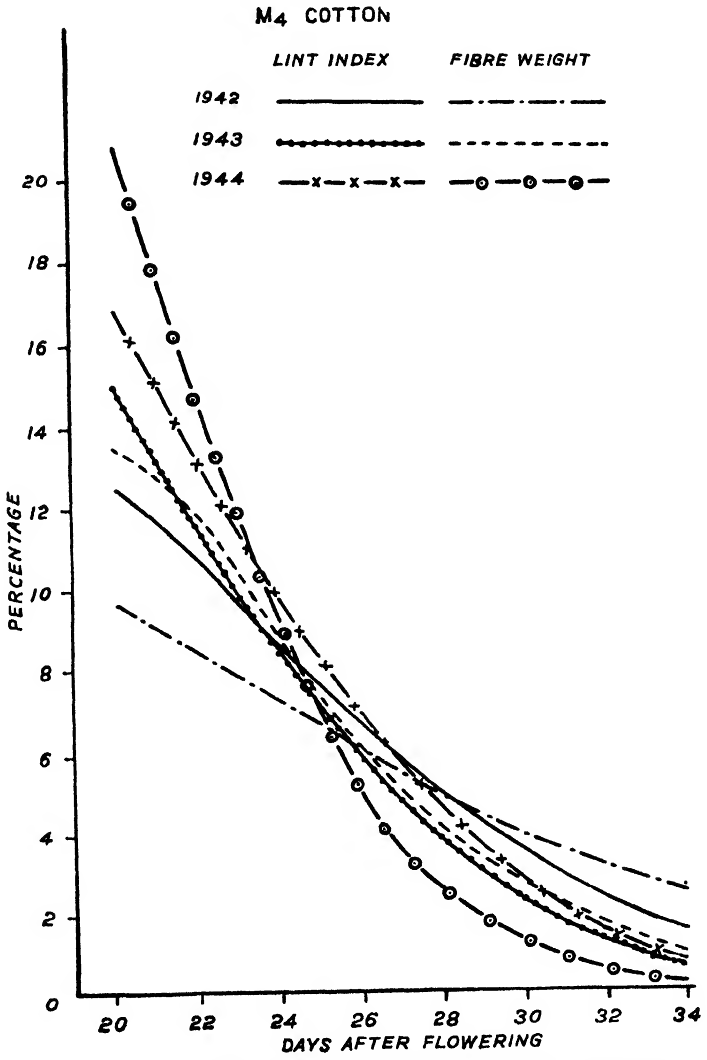

FIG. 7. Relative rate of growth of lint index and mean fibre weight

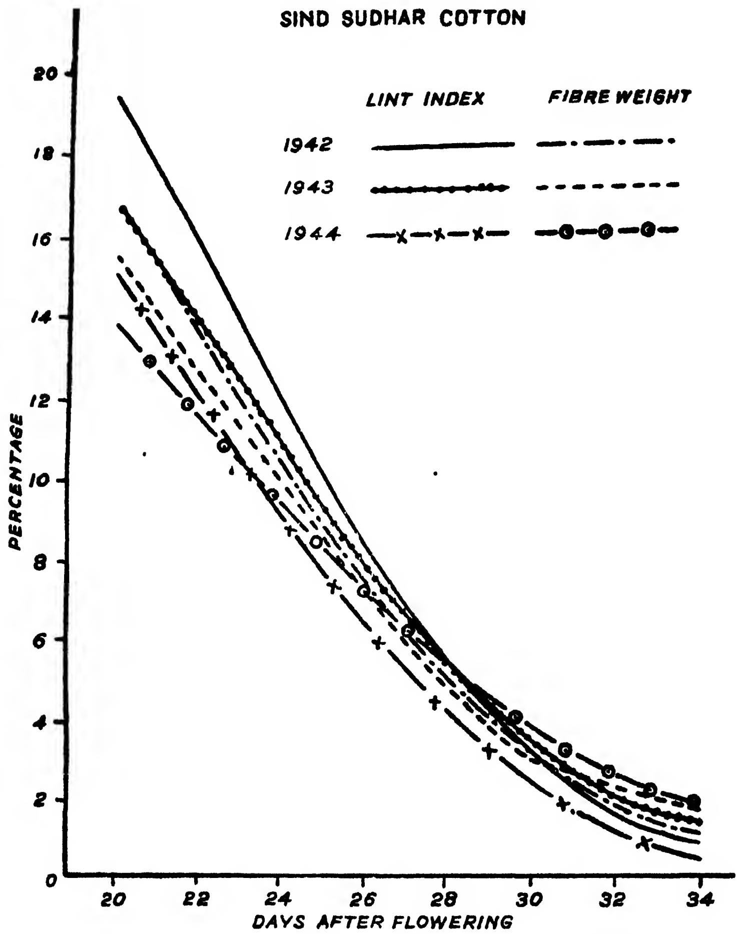

FIG. 8. Relative rate of growth of lint index and mean fibre weight

There is one exception in the case of M-4 for the season 1944-45, when the rate of growth of fibre weight was appreciably higher than that of lint index.

Maturity counts

Maturity of cotton hair is determined in terms of the amount of cellulose deposition. During the first phase of lengthening, the fibre only elongates in the form of a tube. After this period, thin layers of secondary cellulose are deposited, in the form of concentric rings, within the fibre. Some hairs remain thin walled and are classed as dead or immature. Others which are favourably placed to develop normally, are called mature fibres, while those which develop an intermediate thickness of cell wall, are classed as half mature. Thus the percentage of immature fibres would gradually decrease with the advance in the age of the boll.

Actual percentage of mature hairs are given in Table XXIII of the Appendix. The presence of mature hairs right at the start, i.e., on the 19th day, shows that the thickening of fibre wall had already commenced. This process continued right up to the 35th day. The increase in the percentage of mature hairs was rapid up to the 29th day, after which it slowed down considerably, with the result that only in two cases out of six, namely M-4 in 1942 and Sind Sudhar in 1944, the increase in percentage of mature hairs from 29th to 35th day was significant.

These points will be clearer from the study of the following Table, which records the percentage of mature fibres at different ages in both the varieties.

TABLE XVI

Percentage of mature hairs (calculated)

Age of boll in days	M-4			Sind Sudhar		
	1942	1943	1944	1942	1943	1944
19	6	1	2	1	1	7
21	15	6	11	5	6	19
23	32	23	38	22	26	40
25	54	55	69	56	65	65
27	70	74	80	82	87	28
29	78	79	83	91	93	90
31	82	80	83	93	94	93
33	83	81	83	94	94	94
35	83	81	83	94	94	95

On comparing the maturity counts with mean fibre weight per unit length (whole fibre), as given in Table XXI of the appendix, it will be noticed that the changes in fibre weight and maturity are of a similar nature. Most of the fibre weight, like maturity, was acquired up to the 29th day. In two cases out of three an increase in fibre weight after 29th day was accompanied by a rise in maturity. The third case was on the border line of significance. In a few cases it was noticed that though there was practically no increase in maturity, fibre weight showed a steady rise. It could be suspected that this increase might be due to the development of immature hairs into half mature, but this could not be substantiated by the data, which revealed no change in the number of immature and half mature fibres.

Thus, the rise in the mean fibre weight per unit length after the full maturity of the cotton, might be due to the increase in the cell sap in the lumen or some dried residue of boll fluid on the surface of the fibre.

Summary

Study of the growth of certain seed and lint characters during the second phase of boll maturation was undertaken for two Sind American cottons at the Cotton Research Station, Mirpurkhas, Sind.

Differential trends of seed weight and lint index were observed.. In the beginning of the second phase of boll maturation, the relative rate of growth of lint was high followed by a rapid fall in the later stages; but the relative growth rate of seed, though initially much lower than that of the lint, persistently maintained itself with only a slight and gradual fall. Thus the two growth curves gradually converged to a point by about the 27th day after flowering and after intersecting, diverted from each other. This phenomenon was observed in the two varieties at the same stage of boll maturation during the three seasons under investigation. Thus the growth trends of lint and seed were found to be fundamentally different and were unaltered by seasonal fluctuations in lower Sind. However, the angle of intersection was more acute in M-4 than in Sind Sudhar, indicating comparatively less pronounced differences in the growth rates of lint and seed in the former than in the latter.

Maximum ginning percentage for both the varieties was also found to coincide with the day of intersection of the growth curves of seed and lint, falling by two to four per cent in the later stages on account of higher rate of seed development as compared with that of lint.

There was an appreciable increase in the mean fibre length up to the 25th day after flowering. This increase was more pronounced in the case of Sind Sudhar than M-4. Since there was an evidence that cellulose deposition inside the fibres started even before the 19th day it could be inferred that the two phases of development, namely lengthening and thickening, overlapped for some time.

Mean fibre weight per unit length of the middle section was more than the mean fibre weight per unit length of the whole fibre during all stages of the second phase of boll maturation; even the relative rate of growth of the former was higher than that of the latter in most of the cases.

Maturity counts were higher in Sind Sudhar than in M-4 by 10 per cent. Although the maximum values of mature fibres for both the varieties were attained on the 35th day after flowering, values very near the maxium had reached by about the 29th day.

Acknowledgements

The author owes a great debt of gratitude to Dr Nazir Ahmad, O.B.E., Ph.D. (Cantab.), J.P., Director, Technological Laboratory, Matunga, Bombay (now member, Indian Tariff Board) for his inspiring guidance and the most valuable suggestions during the course of this study. Thanks are due to Dr R. Sankaran, Cotton Botanist, Cotton Research Station, Mirpurkhas, Sind, without whose co-operation this work would not have been accomplished. To Mr. R. S. Koshal, Statistician, Department of Agriculture, Bombay Government, are due my obligations for his help in statistical interpretation of the results.

The last but not the least, the paper owes its present reproduction and shape to the invaluable suggestions and guidance of Mr Muhammad Afzal, Cotton Botanist, Cotton Research Laboratory, Lyallpur, who, in his most crowded time, helped me not only in going through the MSS, but bringing the real of the matter out in the proper form.

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APPENDIX (RAW DATA)

TABLE XVII

Seed weight (weight of 100 seeds) in gm.

Age of boll in days	M-4			Sind Sudhar		
	1942	1943	1944	1942	1943	1944
17	..	3·24	2·72	2·47	2·99	3·09
19	3·46	3·68	3·13	3·06	3·54	3·78
21	4·49	4·49	3·78	3·98	3·94	4·36
23	5·35	5·36	4·54	4·29	4·48	4·91
25	5·62	5·92	5·12	5·02	5·05	5·06
27	6·32	6·83	5·72	5·03	5·70	5·70
29	7·54	7·05	6·70	6·62	6·78	6·36
31	8·41	7·64	6·38	6·96	6·62	6·60
33	8·39	8·32	7·59	7·40	7·98	7·67
35	9·20	8·62	7·17	8·21	8·04	7·40

Table XVIII

Lint index (weight of lint on 100 seeds) in gm.

Age of boll in days	M-4			Sind Sudhar		
	1942	1943	1944	1942	1943	1944
17	..	1·03	0·68	0·56	0·75	0·81
19	1·30	1·59	1·08	0·90	1·12	1·15
21	2·16	2·25	1·62	1·62	1·59	1·67
23	2·63	2·78	2·05	2·08	1·99	2·20
25	2·73	3·14	2·48	2·42	2·51	2·25
27	3·26	3·42	2·90	2·59	3·11	2·72
29	3·62	3·70	3·00	3·32	3·36	3·05
31	3·92	4·01	2·92	3·39	3·34	3·08
33	3·91	4·13	3·24	3·48	3·72	3·35
35	4·07	4·25	3·28	3·56	3·48	3·36

Table XIX

Ginning percentage

Age of boll in days	M-4			Sind Sudhar		
	1942	1943	1944	1942	1943	1944
17	..	24·1	20·0	17·1	20·0	20·8
19	27·3	30·1	25·6	22·8	24·0	23·8
21	32·4	33·4	30·0	29·0	28·7	27·7
23	32·8	34·1	31·1	32·6	30·8	30·9
25	32·7	34·7	32·6	32·5	33·2	30·8
27	34·0	33·4	33·6	34·0	35·3	32·3
29	32·6	34·4	30·9	33·4	33·1	32·4
31	31·8	34·4	31·2	32·8	33·5	31·8
33	31·8	33·2	29·9	32·0	31·7	30·4
35	30·7	33·1	31·4	30·2	30·1	31·2

TABLE XX

Mean fibre length in inches

Age of boll in days	M-4			Sind Sudhar		
	1942	1943	1944	1942	1943	1944
19	0·98	0·93	0·95	0·87	0·87	0·95
21	0·97	0·96	1·01	0·90	0·96	0·97
23	0·96	0·95	1·00	0·92	0·99	0·99
25	1·00	1·00	1·02	0·96	1·00	0·97
27	0·99	0·98	1·01	0·97	0·96	0·96
29	0·98	0·96	1·04	0·98	1·00	1·01
31	1·00	0·98	1·00	0·96	0·97	1·00
33	1·00	0·96	1·03	0·99	1·00	1·01
35	0·98	1·00	1·02	0·97	0·99	0·96

TABLE XXI

Mean fibre weight per inch in 10^{-6} oz. (whole fibre)

Age of boll in days	M-4			Sind Sudhar		
	1942	1943	1944	1942	1943	1944
19	·064	·061	·051	·044	·046	·043
21	·080	·081	·075	·061	·064	·060
23	·104	·106	·092	·084	·078	·078
25	·108	·122	·118	·099	·096	·089
27	·130	·134	·136	·113	·120	·107
29	·135	·150	·138	·134	·126	·114
31	·152	·157	·139	·140	·143	·119
33	·154	·164	·149	·142	·146	·139
35	·166	·164	·147	·144	·140	·139

TABLE XXII

Mean fibre weight per inch in 10^{-6} oz. (middle section)

Age of boll in days	M-4			Sind Sudhar		
	1942	1943	1944	1942	1943	1944
19	·066	·063	·049	·041	·046	.042
21	·087	·086	·079	·066	·064	.060
23	·109	·112	·093	·084	·080	·079
25	·116	·132	·123	·102	·101	·091
27	·136	·145	·143	·118	·122	·106
29	·142	·159	·144	·143	·133	·117
31	·163	·169	·144	·149	·149	·120
33	·162	·175	·157	·153	·155	·141
35	·174	·181	·157	·157	·147	·141

TABLE XXIII

Percentage of mature hairs

Age of boll in days	M-4			Sind Sudhar		
	1942	1943	1944	1942	1943	1944
19	5	1	2	1	1	1
21	20	9	17	14	11	11
23	46	50	42	48	32	42
25	62	56	68	62	68	74
27	64	73	79	73	81	76
29	72	79	86	90	94	83
31	80	82	81	94	94	90
33	80	77	85	93	96	97
35	88	82	84	94	92	96

THE SURVEY OF *POLLU* AND ROOT DISEASES OF PEPPER

By K. Krishna Menon, Assistant Mycologist, Indian Council of Agricultural Research

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THIS paper comprises an account of the studies made during a survey of pepper cultivation in South Western India undertaken under the auspices of the Imperial (Indian) Council of Agricultural Research and the Madras Government. The survey was carried out between June and December 1944. During the survey, pepper gardens were visited in Malabar and South Kanara districts of Madras, Coorg, North Kanara district of Bombay Province, and the States of Travancore, Cochin and Mysore. The object of the survey was to assess the importance of *pollu* (hollow berry disease) and root diseases of pepper to the decline of the pepper industry in India. An exhaustive enquiry was made on the role of pests and diseases. Enquiries were also made and observations recorded on the yield of pepper in relation to different tracts, varieties under cultivation, systems of cultivation and manuring, choice of standards and the price trends. The facts elicited during the survey showed that despite the importance of pests and diseases in certain tracts, there existed a variety of agricultural and marketing problems, the solution of which alone would rehabilitate a declining industry. Hence the paper attempts to furnish a comprehensive account of the reasons for the decline of pepper in India and to suggest ways and means to overcome them. Advantage was taken of the survey to make a collection of the available varieties of pepper both cultivated and wild and to propagate them.

Pepper or the 'black pepper' of commerce (*P. nigrum*) is indigenous to the forests of Travancore and Malabar where it has been found growing wild in the rich moist humus soils of the submontane tracts. The crop has been in cultivation in South India from time immemorial. The spice was known and esteemed from the earliest times as evidenced from references to it in ancient Sanskrit literature. It was highly valued by the Romans and for centuries formed an article of trade between India and Europe. It was so highly valued that sometimes it replaced money in certain transactions. Payments of rent used to be made in pepper and often ransom demanded included pepper besides gold and silver. There can be little doubt that the high price of pepper provided one of the main incentives for search to be made for an all-sea-passage to India, and Vasco de Gama's achievements by his discovery of a route to the West Coast of India led to this spice becoming a Portuguese trade monopoly until the seventeenth century. India continued to be the seat of pepper cultivation till the 19th century during the latter part of which the cultivation of pepper was extended to the Malay Archipelago, where it became so thoroughly established that the seat of the pepper industry of the world shifted to this part of the world.

Distribution, climate, rainfall and elevation

Pepper is purely a tropical plant and thrives best in places where the annual rainfall is well over 80 inches per annum and never less than 50 to 60 inches. It prefers a warm and moist atmosphere which is the normal feature of the pepper belt of the West Coast extending from South Travancore in the south to Konkan in the north. The cultivation of pepper is mainly confined to the slopes and lower altitudes and submontane tracts of the Western Ghats. Travancore and Malabar are the most important producing tracts. In parts of South Kanara it is cultivated on a fairly large scale. It is also grown to some extent in Coorg, Mysore, Cochin, and the North Kanara district of the Bombay Presidency. It is also found, grown on a small scale, in Assam and Bengal. Outside India, pepper is extensively cultivated in East Indies, Malaya, the Straits Settlements, Java and the Dutch East Indies. Though introduced from India, pepper now forms one of the most important products of export from these countries.

Pepper is found growing from sea level to an altitude of well over 3,500 feet above the mean sea level. As regards temperature there are no records available for all the pepper growing tracts but from the knowledge of conditions in some, it can be assumed that the maximum temperature during the hot weather will seldom be over 104°F and the lowest temperture which is reached during the months of December to January may be as low as 50°F. Thus it is seen that within these wide limits, the pepper plant can stand a fairly wide fluctuation of temperature

Distribution on the West Coast of India

The pepper growing tracts on the West Coast may be roughly classified as follows :

I. The coastal area where pepper is grown in almost every ' compound ' or plot of land in which a residential building is situated, but where it is seldom cultivated as a pure crop. The number of vines in each compound varies considerably, it being anything from 10 to 100.

II. The slopes and hill valleys where pepper is extensively cultivated as the main crop.

III. The foot of the hills where pepper thrives best and gives the heaviest yield.

IV. The Wynaad hills at elevations ranging from 2,000 to 3,500 feet where the crop is extensively grown interplanted with coffee (*C. arabica*). In recent years pepper in this tract has been on the decline and Arabica coffee is replaced by Robusta coffee (*C. robusta*) and loose-jacket oranges (*C. nobilis*).

Homestead compounds

Both in Malabar and Travancore, almost every compound contains some pepper vines. The number in each compound varies considerably. These vines are mostly trained on mango, jack, areca palm, coconut or any available tree which serves as a good standard. These vines are usually situated far and wide and they

are seldom found suffering from any serious pest or disease. Almost every household in Malabar, Travancore and Cochin is self-sufficient as regards pepper and after meeting its domestic needs the surplus is sold and this is one of the few cash crops of the tract. The produce from the vines formed in these innumerable small compounds contribute very largely to the total production. In the words of the Director of Agriculture, Travancore—

' Very many regular plantations of pepper do not exist here, but pepper grown as a garden crop occupies not an inconsiderable area. The produce from such isolated garden crops constitute by far the largest share of the exports of this commodity which vary in recent years between 40,000 and 50,000 candies (of 500 lb.) of dry pepper annually.'

Cultivated area

Pepper is extensively cultivated in and below the Western Ghats and due to various systems of cultivations which are described later in this report, it is not easy to get at very accurate figures of the acreage under this crop. Only a rough estimate of the area under pepper can be given.

TABLE I

Showing the area under pepper in the different tracts

Tract	Area in acres
1. Malabar	94,685
2. Travancore	89,159
3. South Kanara	8,570
4. North Kanara	2,500
5. Coorg	1,122
6. Mysore	500
7. Cochin	250
Total	196,806

India's place in the pepper trade

Pepper is a commodity in which India had for several years held a predominant place in the world's market. The West Coast of India enjoyed a practical monopoly till the beginning of the nineteenth century when there started a keen competition from the Malay Archipelago. It is a crop of great commercial importance to Madras Presidency since Madras has always taken a preponderating share of the trade in India in pepper as seen from the following Table :

TABLE II

Showing the contribution of Madras Province to the export trade of British India

Year	Quantity in cwt.		Value in rupees	
	India	Madras	India	Madras
1933-34	58,909	50,533	18,23,903	14,54,464
1934-35	71,070	60,681	24,50,390	18,87,591
1935-36	26,415	24,959	7,62,852	7,06,574
1936-37	24,977	23,326	6,08,850	5,64,340
1937-38	17,456	16,148	3,91,616*	3,57,762

In recent years, South India which was once the leader in pepper trade has fallen to the lowest and it contributes only about 2 to 3 per cent to the world export trade as can be seen from the following Table culled from the International Year Book of *Agricultural Statistics* [1938-39].

TABLE III

Annual export of pepper from some important producing countries

Countries	Quantity in metric tons					
	1933	1934	1935	1936	1937	1938
1. Netherlands Indies . .	44,330	48,495	58,747	78,399	31,266	54,814
2. British Malaya . .	16,211	20,437	22,673	10,939	10,885	7,749
3. Java	5,852	4,039	5,011	5,814	1,961	4,575
4. Indo-China . . .	3,679	4,002	3,434	3,901	3,852	5,705
5. Sarawak . . .	3,314	4,765	1,766	2,050	2,209	3,061
6. Others	38,478	44,466	53,736	72,585	29,315	50,239
7. India	3,045	3,333	2,846	722	1,215	703
Total .	1,14,909	1,29,537	1,48,213	1,74,413	80,693	1,26,846
India's share (percentage)	2·65	2·58	1·92	0·41	1·50	0·55

BOTANICAL DESCRIPTION

The pepper plant (*Piper nigrum, L.*) belongs to the natural order *Piperaceae* or pepper family to which also belong the betel vine (*P. betle*) *Thippili* (*Piper longum*) and the *Valmulaku* or the tailed-pepper (*Piper cubeba*).

It is a perennial climbing shrub attaining a height of about 30 feet. The vines are usually trained on various straight-stemmed trees known as 'standards,' whose trunks are clothed with the climbing stems, branches and foliage of the vines. The stems are usually swollen at the nodes, a character which can be seen even in the very older portions. From these swollen nodes numerous adventitious roots commonly called 'clinging roots' or 'climbing roots' are produced, by means of which the plants attach themselves to the standards and climb up the standards to expose their leaves to the maximum light and air. As the stems grow older they become woody with well-developed bark. Pepper plants are long-lived and vines 50 to 60 years old are seen in some parts of Malabar.

The leaves are alternate and simple. Each leaf has a short petiole and a broad oval entire lamina ending in a short acuminate tip. The colour of the leaves varies from light to dark green, shiny on the upper surface but paler and coarse underneath. A leathery texture and pungent taste are characteristic of pepper leaves. Plants grown under shade as in Wynaad remain evergreen but when the shade is not sufficient a partial shedding of leaves is evident in the dry months from March to May. With the advent of summer showers new flush is put forth and flower spikes are subtended from the axils of the new leaves.

The flowers are minute and are produced in several rows on elongated catkins popularly called 'spikes'. The length of the catkin varies with different varieties. The flowers are not showy. They are usually bisexual but some varieties bear dioecious unisexual flowers. Cultivated varieties have usually a higher percentage of bisexual flowers. No variety can be called first rate unless the flowers in a spike are mostly hermaphrodite. Each flower is subtended by a shield-like bract and a smaller bracteole. The perianth parts are absent. In hermaphrodite flowers two stamens are visible, one on each side of the central pistil. Each stamen has a short stalk surmounted by a bilobed anther. The ovary is unilocular with one ovule in it. The style is not conspicuous and is reflexed crosswise from the apex of the ovary. There are four to five stigmatic branches.

The fruit is sessile and berry-like, green when young but ripening into a cherry colour. The outer rind is firm at first, but when the berries ripen it becomes soft and pulpy and easily sloughs off, exposing the hard coat of the single seed. When mature the spike bears several rows of close-set berries.

The factors which determine the yield are mainly (1) the number of spikes in a vine; (2) the length of the spike; (3) the number of berries per unit length; and (4) the number of rows of berries and the density of the berries.

Flushing and pollination

Pepper vines resume their activity after the hot summer months during which there is practically no growth and many leaves are shed. Soon after the commencement of the south-west monsoon the early symptoms of flushing are evident, first in the form of a minute non-elastic brownish cap from the ends of the fruiting branches of the previous season. This cap-like structure is pushed up by the growing sheath underneath. It is sickle shaped and it usually falls off within ten to twelve days of its appearance. Then a minute spike can be seen with a tiny young leaf subtending it. The colour of this leaf is creamy white but the normal green colour gradually developes within six weeks. Anthesis begins about two to three weeks after flushing, and proceeds from the base of the spike to the tip. It takes about a week for all the flowers on a spike to be completely open. The opening of the flowers takes place all the 24 hours of the day though it is more active in the early morning and late in the evening.

The number of flowers in different varieties varies mainly depending on the size of the spikes and the number of flowers per unit length of the spike. The lengthening of the spike is most marked during the period of flower opening. The agency that scatters the pollen grains in different directions and helps in pollination of the flowers, seems to be the heavy driving rains of the monsoon. The number of pollen grains carried by a single spike is estimated at 500,000 to 750,000 and this gives an idea of the large number of pollen grains produced in pepper gardens during the flowering period. One pollen grain being enough to fertilize an ovary, there is ample reserve of pollen for accidental dispersal.

The flowers of pepper are protogynous and the interval between the appearance of the stigmas and the period of discharge of the pollen grains varies considerably. It is found that the stigmas of pepper flowers remain receptive for a period of 2 to 10 days depending on the variety. Generally the flowers of pepper are not self-fertilised but there is a chance for the flowers at the tip of the spike being self-fertilised by pollen grains discharged from stamens at the bases.

Varieties of pepper

Many varieties of cultivated pepper exist. Each tract has its own selection of popular varieties which should have come into existence as true seedlings. Those which are easily distinguishable go by different names in the tracts of their origin. Introductions have taken place from one tract to another with the result that one and the same variety goes under different names in the different areas. For the purpose of this report the varieties found in each of the important pepper tracts will be considered separately. So far no variety of pepper existing in India has been produced as a result of human effort at breeding.

(A) *Malabar and South Kanara districts*

In this tract eight varieties are under cultivation. Some of these are grown over a large acreage while others are confined to particular portions of this tract. The following is a short account of the varieties found in this tract.

(1) *Balamcotta.* This is easily the most popular variety in Malabar and is extensively cultivated in the taluks of Kottayam, Chirakkal and Kurumbranad. It is a medium climber and enjoys the reputation of being a heavy yielder with regular annual bearing capacity. The leaves of this variety are very large in size, easily being the largest of all the varieties—measuring on an average 19 × 11 cm., and comparatively light green in colour. The leaves are oval, being broadest in the middle but the two halves are unequal, one half being broader than the other. The spikes are 12·5 to 19·5 cm. long with big berries. The skin of the berries is thick and the berries are lighter in weight, bulk for bulk than *Kalluvalli*.

(2) *Kalluvalli* (*Kallu.*=stone). Next in importance to *Balamcotta* is *Kalluvalli* which has a fairly wide distribution in this tract. It is a hardy variety and is reported to withstand unfavourable weather conditions better than *Balamcotta*. The yield is good and bearing annual. The leaves are smaller than those of *Balamcotta* measuring on an average 17·0 × 9·1 cm. and are of a dark green colour. They have a tendency to be in line with the internode just below their origin. The spikes vary in length from 8·5 to 17·0 cm. but the berries are very closely set. As the name indicates the berries are heavier and bulk for bulk they register a higher weight than *Balamcotta*.

(3) *Cheriakodi* (*Cheria*=small). This is common in the taluks of Chirakkal and Kottayam and is widely distributed. True to its name the plants of this variety are smaller in size in all parts. The leaves measure 15·5 × 6·75 cm. and are dark green in colour. These project out horizontally more or less at right angles to the stem. The spikes are short, measuring 5·5 to 9·5 cm. in length. The berries though smaller than those of the two foregoing varieties, are close set and packed. This variety is not regular in bearing though in some years it gives a good yield.

(4) *Uthirancotta* (*Uthiran*=shedder). This is not a popular variety though its presence is tolerated in some of the gardens. It is a poor yielder. The leaves are dark green in colour and measure 16·2×8·4 cm. The foliage exhibits some resemblance to that of *Kalluvalli*. A large number of vegetative runners are produced at the base. The spikes are 10·5×19·0 cm. long, but the berries are sparse though large in size. Hence each spike produces a few berries and this affects yield adversely.

(5) *Karinkatta.* This is cultivated in the Wynaad taluk of Malabar and is mostly found in the neighbourhood of Manantoddy. This is a promising variety which exhibits regular bearing and yields well. Moreover it is not as easily affected by unfavourable seasonal conditions as the other varieties. It is a hardy variety living up to forty years. The leaves are very tough, dark green in colour and project out horizontally and measure 16·4×9·5 cm. The spikes measure 7·0 to 11·5 cm. Though short, they are well packed with medium-sized berries. When fully grown, the spikes become twisted in their axis and curved.

(6) *Kallu-Balamcotta.* This variety is popular in the Kottayam taluk of Malabar district round Mattanur and Iritty. It exhibits a combination of the

chief characters of both *Kalluvalli* and *Balamcotta*. It is regular in bearing and gives a heavy yield. The leaves are as big as those of *Balamcotta* measuring 19·75×12·58 cm. The spikes are short and the berries are close set and well packed as in *Kalluvalli*. A few vines of this variety were also found growing in some of the coffee plantations in Coorg.

(7) *Malavalli*. This variety is grown in the vicinity of Mattanur and Iritty in the taluk of Kottayam. It has a general resembalnce to *Balamcotta* but is irregular in bearing. The leaves, though big (18·25×11·65 cm.) as in *Balamcotta*, are of a dark green colour. The spikes are 12·0 to 18·0 cm. long and the berries are close set. But the irregularity of its bearing makes it an undesirable variety.

(8) *Kottavalli*. This enjoys the greatest popularity among the South Kanara pepper growers. It is a very regular annual bearer giving heavy yield. There is a great resemblance to *Balamcotta* of Malabar and it appears that it is the same variety going under a different name in South Kanara.

(B) *Travancore*.

In this part of the country are grown at least a dozen varieties and most of these are pecul ar to this area and are not found indigenous in Malabar or South Kanara.

(1) *Kottanadan*. This is one of the popular varieties of Travancore and is largely grown in the South and Central Travancore. It is a hardy variety which comes up well even in areas of less than 80 inches of rainfall. It is a good climber with regular bearing habits and gives a heavy yield. The leaves measure 14·0×8·0 cm. The spikes are 7·0 to 13·5 cm long with close-set medium-sized berries. When mature a twist is developed in the spike as a result of which five twisted rows of berries are borne in each spike. This variety is known in some places as '*ayimpiriyan*' meaning one with five twists. Occasionally some spikes exhibit branching, and 3 to 5 branchlets may be given off from each spike.

(2) *kaniakadan*. This is more common in tracts in Central and North Travancore which receive a heavier rainfall than the south. It is easily the best variety of the State and is a great favourite of the planters and the traders. Among traders it goes by the name of 'Palai pepper' (after the name of a town in Central Travancore and usually fetches a premium of Rs. 10 per candy of 500 lb.). Two types of this variety are in existence— *Valia Kaniakadan* and *Cheria Kaniakadan* and between the two the former is more extensively cultivated. Both are good yielders and bear annually. The leaves measure 14·0×6·0 cm. The spikes vary in length from 7·5 to 16·5 cm., *Cheria Kaniakadan* as the name implies has shorter spikes and smaller leaves.

(3) *Perumkodi.* - This is cultivated in Central and North Travancore. It is also known to be a good yielder, bearing yearly. The vines are sparsely leaved and the leaves measure 13·0×7·0 cm. The spikes vary in length from 10·5 to 17·5 cm.

(4) *Karivilanchi.* Though it is found all over the State, it is more common in Central and South Travancore. It is a hardy plant exhibiting a great resemblance to *Kalluvalli* of Malabar. It is favoured by the cultivators and traders. This variety usually gives a good yield and bears yearly. The leaves are dark green in colour and measure 12·5×8·0 cm. The spikes vary in length from 6·0 to 14·0 cm. and is closely packed with medium sized berries.

(5) *Karivalli*—(*kari*=dark). This is also confined to Central Travancore. It is a good climber but irregular in bearing, good yield being obtained in alternate years. The leaves are broad and measure 16·5 × 10·5 cm. The spikes vary in length from 11·0 to 19·5 cm. Though the spikes are long the berries are not close set.

(6) *Mundi.*—This is more common in North Travancore. It is a hardy variety flowering early in the season and coming to harvest in November-December. It bears annually and gives a good yield. The leaves measure 14·0 × 7·5 cm. The spikes vary in length from 7·0 to 13·5 cm. and berries are big sized.

(7) *Munda.*—This is also found in North and Central Travancore and more or less resembles *Mundi* in appearance. It is a medium climber and a poor yielder The leaves measure 11·5 × 7·5 cm. The spikes vary in length from 6·0 × 14·0 cm. but the berries are big. The produce is harvested in December-January, thus is later than the harvest of *mundi.*

(8) *Thulakodi.* It is found largely in Central Travancore and is an early variety. It flowers in April to May and is harvested in October-November. It is a medium climber, yearly bearing, and a good yielder. The spikes vary in length from 6·5 to 12·5 cm.

(9) *Arikottanadan.*—It is found in Central and South Travancore and resembles *Kottanadan* except that the berries are smaller in size. The spikes vary in length from 7·5 to 14·0 cm.

(10) *Kuthirawali* (*horse-tail*).—It is found round about Kottarakara and southern taluks. It is a medium climber, yearly bearing and a good yielder. The spikes are long ranging from 11·0 to 17·0 cm. and hence the name. The leaves measure 13·5 × 9·25 cm.

(11). *Karinthakara.* It is found in Central Travancore. It is a bold climber, a good yielder but bears only in alternate years. The leaves measure 12·0 × 7·0 cm. and the spikes vary in length from 5·5 to 13·0 cm.

(12) *Kumbakodi.*—It is confined mainly to Central Travancore. It is a late variety, the produce being harvested in February-March. The name of the variety itself indicates the month of harvest Kumbam (Malayalam)=February-March. It is a hardy plant, bears annually but gives only medium yield. The leaves are rather broad and pale green in colour and measure 13·5 × 9·5 cm. The spikes vary in length from 8·0 to 14·5 cm. The berries are not very thickly set.

(13) *Chumala.*—This is found in Rani and Pattanamthitta. The leaves are broad and large and pale green in colour and measure 18·5 × 10·25 cm. The growing tips have a light pinkish colour and hence the name '*chumala*'. It is an early variety, flowers in April-May with the early rains and is harvested in October-November. The spikes vary in length from 11·0 to 16·5 cm. and the berries are well packed. It is a bold climber.

A spreading variety of pepper

This variety was found growing in two estates in Travancore State (1) Perumila Tea Estate (Konni) and (2) Malankara Rubber Estate (Todupuzah). It grows like a shrub and does not require a standard. Adventitious roots are not formed at the nodes. A plant five years old was found to have covered an area of six feet in diameter. The leaves are light green in colour and measure 12·25 × 9·45 cm. The flowers are hermaphrodite. The spikes are of medium size and vary in length from 8·0 to 12·0 cm. and fully packed with berries. The berries are small in size and are quite pungent to taste. The owner said that he got 3½ pounds of dry pepper during the previous season.

The owners were not able to account how this variety got introduced in their estates but they believe that they grow from seeds dropped by birds.

(C) Mysore and North Kanara

The main varieties under cultivation are the following :

(1) *Malligasara.* This is one of the most common varieties cultivated in North Kanara and Mysore. It is a medium climber, annual bearer and a heavy yielder. The leaves are dark green in colour measuring 17·75 × 12·0 cm. The spikes are medium sized and vary in length from 8·0 to 12·0 cm. and the berries are well packed and close set. It is known as *Mallisara* in North Kanara and is one of the most popular varieties cultivated there, yielding better than other varieties. The berries are very pungent and weigh more than others bulk for bulk.

When ripe the berries are shed and so the crop has to be harvested before the berries ripen. A pale green and a dark green variety go under the same name but the former is the more common and widely cultivated one, while the latter is said to do better in places, where the soil dries up quickly.

(2) *Morata.* -This is not a good variety and is a poor yielder. The leaves measure 16·40×12·3 cm. The spikes are short 5·0 to 8·0 cm. long and curved. The berries are small, and individual berries are not shed when ripe, but the spikes fall off quickly, thus rendering the harvest easy.

(3) *Arisina morta.* –This resembles *Morata* except that the berries when ripe are yellow in colour, hence the name.

(4) *Doddiga.* -This is a medium climber with big leaves measuring 19·35×11·5 cm. The spikes are medium sized 7·50 to 0·5 cm. long, the berries are big and well packed and close set. It is reported that in years of well distributed and heavy rainfall this variety gives a bumper crop.

(5) *Tattisara.* -This is also a good variety, a good climber and a regular yielder. It is reported that the variety flourishes in comparatively drier situations better than in very moist localities. The leaves are dark green in colour and measure 15·50×11·5 cm. and the spikes vary in length from 8·5 to 11·5 cm. Unlike *Mallisara* the berries are not shed when ripe which is an advantage in its favour.

(6) *Vakkal Gooja.* This is a poor yielding variety and as the name indicates one seeded and only a few berries are formed here and there on the spikes. The leaves are light green in colour and measure 13·75×8·0 cm. The spikes are short varying from 5·5 to 8·5 cm. in length. Though an early maturing variety it does not find favour with the ryots because of its poor setting of berries.

(7) *Mottukara.* This is a bold climber and a regular yielder. The leaves are almost round in shape 15·0×13·0 cm. and are dark green in colour and tough in texture. The spikes are short varying from 5·0 to 8·0 cm. The aerial climbing roots take a firm hold on the standard and for this reason the growing shoots do not require tying up to the standard after the first two years. It is, however, a slow grower.

(8) *Varieties introduced from Malabar.*- The two main Malabar varieties *Balamcotta* and *Kalluvalli* which have been introduced both in Mysore and North Kanara some 15 years back are found to do well. At Marathur farm which was originally an arecanut Research Station.

of the Mysore Government, these two varieties are being grown side by side with the indigenous ones, but the introduced varieties were found to have established better and yielded higher than the local ones. The average yield of the Malabar varieties per vine was about 2 lb. while the yield of the locals was from half to one pound. Some of the Malabar vines have given yields of over 5 lb. per vine and they have maintained this superiority in yield for some years. Unfortunately this farm was closed down and sold to a private individual who does not take much interest in the cultivation of pepper. Even now it is found that the majority of the vines in the garden are either *Balamcotta* or *Kalluvalli*. *Balamcotta* appears to thrive better than *Kalluvalli* in this locality. The soil is laterite loam and is well suited for pepper cultivation. The vines receive the benefit of cultivation and manuring given to the arecanut palms. There is scope for extension of these two Malabar varieties, viz., *Balamcotta* and *Kalluvalli* in Mysore as well as in North Kanara. Experienced growers stated that the produce of the Malabar varieties, though they gave higher yield than the local one, were lighter in weight by about six per cent bulk for bulk.

Introduction of new varieties

From the foregoing notes on the performances of varieties in different tracts it is obvious that introduction of new varieties is advantageous under certain conditions, but it should be done with caution and proper attention should be bestowed on the suitability of the land and the climatic conditions of the locality, where it is proposed to introduce new varieties. The abrupt transition to a different set of climatic conditions may have some adverse effect on the vitality of the vines. In this connection mention should be made of the experience of some growers that cuttings taken from places of higher fertility and heavier rainfall to places of lower fertility and lighter rainfall failed to thrive in their new surroundings.

PROPAGATION

Pepper can be propagated from seeds and vegetatively from cuttings of the vine. The plantation practice adopted over the whole area is to propagate from cuttings. Propagation from seeds is not only a laborious and uncertain method but also one which will take a longer period for the commencement of flowering and bearing. But it is the one method of evolving new varieties and can be utilized only on research and breeding stations. The pepper growers who are always anxious for quick returns, adopt the vegetative method of propagation only. The technique adopted by the growers varies to some extent in different tracts. The following are some of the methods :

(1) The vegetative shoots or ' runners ' as they are commonly called, are taken from the base of the vine. These runners are selected, coiled and kept poised in air in the fork of a stick planted near the parent vine, so that they do not come in contact with the soil. If these are allowed to come in contact with the soil, adventitious roots will be formed at the nodes and the runners will become useless for planting. Experience shows that cuttings which are formed roots at the nodes are not good for planting, since they fail to establish.

All good growers adopt this method but those who depend on outside-agencies for the supply of their planting material often get bad or indifferent material. There is no fool-proof method by which the cuttings from desirable varieties could be identified at the initial stage and the performance of the planted material could be known only after about five years when the vines begin to yield. Hence it is essential that the selection of good and quality cuttings should be done at the time of planting as otherwise all the labour and expenses involved will be a waste. One should, as far as practicable, take cuttings from selected vines from his own garden or at least from a reliable planter. The general method adopted by the growers in most of the pepper growing tracts is to plant cuttings. The vegetative shoots from the upper portions of the vine are not as a rule used for planting, as experience shows that it is difficult to get them established on the standards.

Planting cuttings of fruiting branches

(2) In some localities like Travancore and North Kanara some growers use planting material from the fruiting branches and it is their experience that the plants from these cuttings began to bear even in the second year and produce a sizable crop from the fourth year onwards, while plants raised from vegetative runners begin to yield only from the sixth or seventh year. But as a set off to this precocious bearing the effective bearing period of these plants is reported to be reduced by about three to five years. The total yield of these plants was in no way reduced. Vines so raised were found to produce no vegetative runners or if they were produced, they were very few in number. This method of propagation can be advantageously taken up by those planters who plant pepper as an intercrop in coconut plantations. By this method they get a quicker return than by the ordinary method of planting vegetative cuttings.

One serious drawback, however in the advocacy of this system is the difficulty to get a sufficient quantity of planting material, as the average grower will not easily part with the fruiting branches from a good vine. But to the extent they become available. e.g., when standards are damaged by wind or by othe causes. this system can be employed. All the fruiting branches of such vines, if they are of high yielding strains, may be taken and planted in a nursery, and with proper care and attention to watering and shade, most of the planted cuttings can be made to strike roots and enough material can be had for planting during the next season. One or two rooted cuttings will be sufficient for each standard.

Layering

(3) In most localities of Malabar and South Kanara, the practice of raising layers in baskets is adopted by growers. Shallow bamboo baskets 2 to 3 inches in depth and 6 to 8 inches in width are filled with pot earth or with good surface soil and selected runners are layered. Within 4 to 6 weeks when roots have formed the layers are carefully separated from the parent plant and planted in prepared pits of $1\frac{1}{2} \times 1\frac{1}{2} \times 1\frac{1}{2}$ feet, near the base of the standards. Sometimes coconut husks are used in place of baskets. By this method almost cent per cent of the cuttings planted out would get established. This method can be resorted to mostly

to fill up gaps but cannot be practised on a large scale. Transport is an important consideration. One workman cannot carry more than 6 to 8 baskets at a time and hence the layering is best done in the same garden, where the layerings have to be planted.

(4) *Rooted cuttings.*—The use of rooted cuttings is made by some planters in Coorg. The cuttings from selected vines are taken and planted in a small nursery at the end of October when the soil is still moist. With proper attention to watering and provision of suitable shade they are induced to strike roots early. Being a small area the planter's personal attention can be bestowed to it. These rooted cuttings are then removed with a ball of earth and planted during the next July. This method is said to give more than 90 per cent success but is not practised on a large scale at present.

(5) *Layerings trained on stakes.*—This is a common practice in gardens where vines are trained on arecanut trees. Stakes of arecanut stem about 6 feet $\times$ 4 inches are driven into the soil about 2 to $2\frac{1}{2}$ feet away from the parent vine and the vegetative runners from the base are trained on to the stakes along the ground and tied. Roots are formed at the nodes, which are lightly covered by soil. As soon as the roots are sufficiently developed, the layers are carefully severed from the parent plant and planted near the base of an arecanut tree. Casualties among such layerings are usually very low and by virtue of an early start in growth they begin to bear earlier than vines raised from ordinary cuttings. Another method adopted in these tracts, is to allow the vegetative runners, from the base of a good vine to creep along the ground towards one of the adjacent arecanut trees, on which a new vine has to be trained. The runners are covered over with soil to the length of two to three internodes, from where rooting takes place. As the runners thus layered grow in length the growing shoot is tied to the arecanut tree selected. When the layering is well established it is severed from the parent vine.

(6) *Nursery for cuttings.*- It is the experience of most pepper planters that failures among ordinary cutting planted directly under the standards is very large. In some cases it is reported that even 60 per cent of the planted cuttings fail to establish. For this reason, the use of rooted cuttings or layered plants is well worth the serious attention of the pepper planter. A large number of small nurseries can be raised in the same garden so that there will be enough planting material. This system can be of special advantage if the planting material is selected in the month of October or November when the vines will be in full bearing so that cuttings for the nursery can be taken from selected vines. This was tried with success at the Agricultural Research Station, Taliparamba, in the year 1941-42. Milsum [1930] reports that this system of raising nurseries is practised in Malaya.

It is also noted that the plants raised from rooted cuttings or layerings come to flower earlier than the ordinary cuttings, since they get one year's growth in the nursery. This method can be adopted with advantage on a large scale in all the

pepper-growing tracts. There is not much difficulty and the only condition necessary is that there should be facilities for copious watering and provision for adequate shade during the summer months. Cuttings from selected high yielding individual vines may be planted in small nurseries so that they can be planted in selected portions of the field and the performance of the offspring can be tested and verified.

CULTURAL METHODS

There is wide variation in the methods of cultivation adopted in the different pepper-growing tracts and they may be roughly classified as follows :

(1) The Malabar and South Kanara system.
(2) The Travancore system.
(3) The North Kanara and Mysore system.
(4) The Coorg system.

The Malabar and South Kanara system

(1) Virgin jungle lands are selected and cleared of all undergrowth trees and stumps of dead trees . Pits $1\frac{1}{2} \times 1\frac{1}{2} \times 1\frac{1}{2}$ feet are dug in rows, the spacing between adjacent pits varying from 8 to 12 feet according to the fertility of the land. In South Kanara 1,000 vines are planted in three acres. The pits are then filled with loose jungle earth and leaf mould. With the advent of the first rains in May or June *Murukku* (*Erythrina indica*) standards, raised from seeds are cut and planted. The method of raising *Murukku* standards is described later in this report under the heading 'Standards'. Within a fortnight these standards strike roots and get themselves established. When the weather conditions are favourable and the monsoon sets in, pepper cuttings are planted near the base of these standards. Usually five cuttings 2 to $2\frac{1}{2}$ feet long are planted to each standard. These cuttings are planted fan-wise either on the northern or eastern side a little away from the standard and not all in one pit. The southern aspects are always avoided as the afternoon sun in summer months may kill the plants outright or cause 'sun burn'. The soil around the planted cuttings is pressed hard and made sloping away from the standard to prevent rain-water stagnating. The portions of the cuttings above ground are pressed close to the standard and tied. Mulch is provided by putting grass or small twigs round the planted cuttings. The tying of the growing cuttings is attended to periodically, keeping pace with the growth of the vines. In the first year they grow to a height of 4 to 5 feet.

During the first year two diggings and weedings are given to the whole area, one in July after the commencement of the South-west monsoon and the other in November, soon after the North-east monsoon. *Lantana* is a troublesome weed in newly planted pepper plantations in hill slopes and these have to be removed, root and branch.

Mulching

To protect the young pepper plants from the heat of the sun during the summer months a bunch of leafy twigs of *irul* (*Xylia dolabriformes*) is tied over them in March but removed with the onset of the monsoon. This shading is done for the

first two years and later only those plants which need protection from the sun are shaded. Too much exposure to sun certainly affects the vines adversely. During the second year practically the same cultural operations are repeated but in the third year besides these operations, the side branches of the standards are pruned and trained to grow straight. Cultural operations during the fourth and fifth years are the same as those in the third year. Lopping of standards is regularly done from the fifth year onwards to regulate shade.

Filling up gaps

This is an item which has to be attended to regularly during the first two to three years. It is not an uncommon sight to see vines of different ages in the same plantations although the original planting was done at the same time. Such disparities in age are attributable to casualties which have to be replaced at different periods.

The Travancore system

(2) The pure crop system practised in Travancore is different from what obtains in Malabar and South Kanara. Virgin jungle is selected but instead of complete clearing of the jungle growth as practised in Malabar and South Kanara the undergrowth of shrubs and weeds is first cleared and some of the standing trees are utilised as standards. Thinning of standing trees is done to provide some sort of spacing. For this reason trees of various sizes, ages and species are found in typical pepper plantations of Travancore. In this system there is considerable variation in the number of vines planted to the acre. The estimation of yield per vine is also rendered difficult as the vines trained on different standards are of different sizes. The number of cuttings planted under each standard depends on the size of the standard.

Planting of cuttings

A semi-circular pit is dug round the northern and eastern sides of the standard and cuttings of pepper vine varying from 3 to 15 in number depending on the girth of the standards, are planted and the free ends of the vines tied to the standard. During the first two years the plantations receive a good digging in July and weeding and chop-digging in November-December, and afterwards most of the planters do only the ' ring ' cultivation. The whole area is weeded but digging is given to the area immediately around the vines. When the land is sloping and the cuttings are planted on a slope below the standard a system of ' crescent terracing ' is done to prevent erosion of soil around planted vines.

Lowering of the vines

The operation of ' lowering ' the already established vines in the second year after planting is practiced in South and Central Travancore by some growers. In the second year after planting, the young vines are carefully pulled away from the standards and a portion of the aerial growth is buried in a trench made near the standards. This encourages rooting of the buried nodes and gives a bushy growth from the bottom of the vines. But since it is a laborious and costly process it is not widely adopted. It is reported that such lowered vines thrive better and yield more than others.

In North Travancore besides the pure pepper plantation, a system of mixed cropping is adopted. Pepper forms mostly an inter-crop in coconut plantations. Pepper and coconut are planted at the same time, the former occupying the intervening space between the coconut seedlings. Under this condition, pepper is kept on the plantation for 12 to 15 years, by which time the coconut trees come into full bearing, when the vines either perish or deteriorate. Usually standards of *Erythrina indica* are used but unlike the practice in Malabar the cuttings are taken from old grown-up trees and not from seedling trees raised specially for this purpose. In Malabar, seeds of *E. indica* are sown and the seedlings are allowed to grow for three years. They are then cut close to the ground and planted as standards. Standards raised under this system are said to strike roots better than the cuttings taken from grown-up trees.

The North Kanara aud Mysore system

(3) In North Kanara and Mysore, pepper is grown mostly as a subsidiary crop in arecanut gardens along with cardamom and bananas. The arecanut trees form the standards for pepper. The arecanut gardens are situated at the lower slopes of valleys. As natural drainage is defective in such situations, elaborate arrangements are made for drainage. The area of individual gardens varies from 2 to 10 acres but the majority of the holdings are below 5 acres. The owner farmers who live near their gardens personally attend to the cultural operations. The arecanut trees receive manuring regularly. The gardens receive clean cultivation, the weeds are removed and a digging given. In alternate years a heavy application of green leaf mulch to a depth of 2 to 3 feet is given. Cattle manure at the rate of one basketful (25 to 30 lb.) is applied to each tree in the next season. The pepper vines receive the benefit of the attention bestowed on the areca palms on which they are trained. In most gardens bananas are grown and those which grow to a height of 18 to 20 feet more or less shut out direct sunlight from the ground. While this is good for cardamoms, it is of very doubtful value to pepper. It is found that under such shady conditions more spikes are formed at the top than at the lower reaches of the vines. If proper attention is paid to the selection and propagation of good varieties and also to the regulation of shade, the yield of pepper can, no doubt, be increased. In no other tract does pepper receive the benefit of such regular and systematic manuring.

No special cultural operations are done to the pepper except the tying of the vines to the standards to assist their climbing. This operation is carried out regularly either in May just before the monsoon sets in or during the break of the monsoon in September. The leaf sheaths of areca palms are torn into strips and these are used for tying the vines to the areca stem. Unlike *E. indica* and other trees with coarse bark, the areca palm does not offer a good hold for the aerial climbing roots of pepper. For this reason this defect is largely made up by more elaborate system of tying of growing shoots. About 20 strings being tied to a full grown vine. The vegetative runners arising from the base of the vines are layered and trained on the standards. By this system the areca stem is covered by the vine all round. This practice is well worth introduction into other pepper-growing tracts.

The Coorg sysime

(4) Pepper is generally planted as a subsidiary crop in the coffee plantations and trained on the shade trees. The common shade trees in coffee plantations are (1) silver oak (*Grevillia robusta*), (2) *thari* (*Terminalia bellerica*), (3) *mathi* (*Terminalia tomentosa*), (4) *bilwara* (*Albizzia odoratissima*) and *honne* (*Pterocarpus marsupium*). Pepper is not grown in all coffee estates, but it is grown largely in South Coorg, round Polibetta, Thithmathi, Ponnampet, Ammathi and Sidapur. The average number of vines per acre varies considerably and it may be anything from 10 to 40. It is not possible to correctly estimate the number of vines per acre in a coffee-*cum*-pepper plantation. Usually three to five cuttings of 2 to 2½ feet in length are planted in July to a standard either on the east or northern side. As in other tracts the western sun is usually avoided. Some planters use rooted cuttings and plant them with a ball of earth. Once the vines are established, they do not receive any special attention or cultivation, but they receive the benefit of the periodic manuring, weeding and other cultural operations given to the coffee. The vines are found thriving well and grew to a height of 30 feet on some of the shade trees. The yield of vine in full bearing varies considerably from 5 lb. to 25 lb. per vine depending on seasonal factors. There is practically no recurring expenditure except the cost of harvesting.

STANDARD S

Pepper being a climbing plant, supports or 'standards' as they are called, are provided prior to the planting of vines. These 'standards' besides serving as supports provide 'shade' for the pepper plants. In South India live standards are as a rule favoured, while in the Malay Archipelago it is reported that 'dead' sandards are provided [Milsum, 1930].

Raising of murukku (Erythrina indica) standards in Malabar and South Kanara

The seeds of *E. indica* are sown along with hill paddy *punam* cultivation and after the harvest of the paddy crop the *Erythrina* seedlings are allowed to grow undisturbed. When the plants have grown to about 5 to 7 feet in height and 6 to 8 inches in girth they are cut close to the ground and stacked horizontally in shade for 2 to 3 weeks. The stumps are then removed and kept in a slanting position at about an angle of 60° for about a month when new shoots will be produced and roots begin to develop at the cut ends. They are then ready for planting and are planted in pits of 1½ × 1½ ×1½ feet, 8 to 12 feet apart depending on the fertility of the soil. Three weeks later when the standards have established themselves, pepper cuttings are planted at the base of the standards and tied to them. In Travancore, branches of *Erythrina indica* are cut from old grown up trees and planted as standards and not grown specially from seeds as is practised in Malabar and South Kanara. It is reported that in Travancore the standards of *E. indica* are of much shorter duration than in Malabar and this is probably due to the difference in the method of raising the standards. Though *E. indica* standards have certain defects such as having shorter life than many of the other standards and of shedding its leaves in the hot weather, it is still one of the most common standards for pepper. The following are some of the points in its favour : (1) It can be easily propagated and is a quick

growing plant ; (2) it is a straight growing plant without many side branches ; (3) the aerial climbing roots of pepper get well established in the early stage as the bark of *E. indica* is rough and secretes a stricky fluid which enables the roots to get a firm hold ; (4) it can stand the annual lopping without serious deleterious effects ; (5) it is a leguminous plant and enriches the nitrogen content of the soil.

Besides *E. indica* the most common standards used are *karayan* (*Garuga pinnata*), *ambazham* (*Spondias mangifera*), *thani* (*Terminalia belirica*), *alam* (*Careya arborea*), *maruthi* (*Terminalia paniculata*), *venga* (*Pterocarpus marsupium*), mango (*Mangifera indica*), teak (*Tectona grandis*) and silver oak (*Grevillea robusta*).

Lopping of standards

The idea of lopping is to regulate the shade and allow more sunlight and air to the vines at a period when they need them most. This is usually done in June-July with the commencement of the rains for all standards except *E. indica*, which is generally lopped in March which is a dry month and the plant sheds all its leaves. *E. indica* is not lopped during the rainy season, i.e., June-July, as the cut ends are reported to harbour wound parasites which cause ' die back '. Lopping of standards is usually done in alternate years, but the wisdom of this practice is not clear. It would be desirable to study this question in detail at an experimental station.

The effect of standards on the vine

No experiment has so far been done on this aspect and therefore it is difficult to form any definite opinion. Pepper being shallow rooted, the root system of deep rooted trees would not compete with pepper for sub-soil nutrition. The effect of standards on the vine, if any, would appear, however, to be more mechanical than physiological, in that they serve as support, and the facility with which the adventitious roots of the pepper plant are able to grip the bark is a factor which may vary with different species of trees and with different varieties of vines. There is, however, reason to believe that some standards deplete the food ingredients from the soil in the feeding region of tye vines to a greater extent than others and this is another factor which varies with standards. Observations made during the survey show that vines growing on dying and dead standards thrive well and yield better crops. The experience of growers may be summarised in the following words : " A good standard means a good vine."

Dead standards

Milsum [1930] states that in China and Malay Archipeiage the pepper vine is trained on dead standards and the yield is reported to be good. An attempt was made at the Agricultural Research Station, Taliparamba, to find out if the vines could be successfully trained on dead standards. Vines were trained on dead standards of irul (*Xylia dolabriformis*). The standards decayed before the vines reached the effective bearing period and the idea was given up.

MANURING

Local practices

This aspect has not received much attention so far. Some cultivators apply cattle manure and leaf mould and their experience is that it pays to manure the vines as the yield is increased. But, as a rule, cultivators do not apply any other

manure except the leaves and twigs of lopped branches of the standards once a year. The organic matter thus applied is too meagre to meet the requirements of the vines and while the crop is able to maintain itself in virgin soil for some years, sooner or later the crop deteriorates, the yield gradually going down year after year. Cattle manure is not used not due so much to want of knowledge of the beneficial effects of the manuring as the non-availability of cattle manure. What little cattle manure the cultivator has, he applies to the paddy crop under a mistaken notion that it gives a quick return. During the survey it was noticed that some ryots use even the loppings from the standards as green manure to the paddy crop.

Manurial experiments

Very few experiments on the manurial requirements of this crop have been done and of these, two which were conducted at the Agricultural Research Station, Taliparamba, may be mentioned. The first experiment was for the purpose of comparing the relative efficacy of organic manures.

TABLE IV

Results of manurial experiments conducted at the Agricultural Research Station, Taliparamba, during the years 1918 to 1928

Treatments	Average yield of green pepper in mm. per 100 vines	Average yield taking control as 100
1 Fish guano ½ lb. per vine	102·6	172·7
2 Fish guano ½ lb. lime ½ mm. 20 lb. leaf mould in alternate years	91·3	153·5
3 Green leaf mulching	86·7	146·0
4 Leaf mould 20 lb per vine	80·8	136·0
5 Lime ½ mm. *plus* 20 lb. leaf mould per vine	62·2	109·8
6 Control (no manure)	59·4	100·0

NOTE. 1 mm. of green pepper=2½ lb. and one mm. on drying will give 1 lb. (approximately)

Results

Fish manure gave the highest yield followed by (1) Fish guano and leaf mould. (2) leaf mulching, (3) leaf mould. It is interesting to note that mere leaf mulching of the soil increases the yield.

The second experiment carried out by the Government Agricultural Chemist at the Agricultural Research Station, Taliparamba, attempted to find out the manurial requirements of pepper. The following Table gives the results of the experiment.

TABLE V

Showing the results of manurial experiments

—	Yield of green pepper on original population basis (average of 10 years)			
	Limed series		Unlimed series	
	Tolas per vine	Percentage increase	Tolas per vine	Percentage increase
No manure	5·7	..	2·2	..
Nitrogen (sodium nitrate)	8·3	45·6	4·9	122·7
Nitrogen + potassium sulphate	15·5	172·0	7·6	245·5
Nitrogen + superphosphate	17·0	138·3	9·0	309·1
Potash + phosphate	15·8	177·2	6·1	177·3
Nitrogen + potash + phosphate	8·9	56·1	6·3	181·9

N = $\frac{1}{4}$ lb. sodium nitrate per vine
K = $\frac{1}{4}$ lb. potassium sulphate per vine
P = $\frac{1}{4}$ lb. super phosphate per vine

The general mean of the limed series is nearly double that of the unlimed series, the beneficial effect of the lime is clear. All the manures have responded well in both limed and unlimed series, the maximum yield being with nitrogen *plus* phosphoric acid in the presence of lime, closely followed with narrow limits by K P, N K and N K P, and with the least response from nitrogen only. The results indicate that leaf mould (20 lb.) *plus* fish guano ($\frac{1}{4}$ lb.) per vine as well as artificial (sodium nitrate $\frac{1}{4}$ lb., potassium sulphate $\frac{1}{4}$ lb., super $\frac{1}{4}$ lb.) answered the requirements of pepper generally.

Both these experiments indicate the need of application of calcium and it is known the Malabar soils are notoriously deficient in this mineral. In assessing the above results of this experiment, the lay out and the selection of planting material for the various treatments, left much to be desired due to the following factors: (1) The planting material was taken from different vines; (2) the plot selected was slopy and had a southern aspect which has a deleterious effect on the crop. There is scope for laying out a correctly-planned experiment with planting material of the same age and selected from uniformly high-yielding vines and in a block of land of uniform fertility. In this connexion it may be mentioned that the best method of obtaining uniform planting material for experiments of this kind is as follows. A large number of cuttings cut from a single high-yielding vine can be first planted in a nursery, allowed to root and then transplanted in the experimental area. This will give a more or less uniform stand.

TABLE VI

Results of the manurial experiments conducted by the Agricultural Department, Travancore, at the Agricultural Farm, Konni

Year	Yield of green pepper in lb.	
	Manured	Control
1929	16	13
1930	36	25
1931	30	28
1932	40	28
1933	50	32
1934	52	40

Manure applied was a mixture of 10 lb. leaf mould, 3 oz. ammonium sulphate 10 oz. super-phosphate. Control received only 10 lb. leaf mould. The results indicate that nitrogen *plus* phosphoric acid increased the yield.

Milsum [1930] reports the use of burnt earth as a manure for pepper was commonly practised in the Straits Settlements in the past and is considered of primary importance in the cultivation of this crop in Sarawak. Bushes, branches of trees and other vegetable matter are collected and heaped and partially sun-dried. Soil is then added until the whole forms a large heap. The wood is then ignited and the heap allowed to burn. The resulting burnt earth and wood ashes are thus applied to the base of the pepper plant several times during the year.

AFTER CULTIVATION

Digging

Two diggings and weedings are given, the first in June to July soon after the commencement of the south-west monsoon. The second in the month of October to November soon after the north-east monsoon. The object of the first digging is to conserve the rain water and minimize surface wash. The object of the second digging is to keep the soil loose with a view to conserve the soil moisture. Most cultivators do these operations regularly year after year. It is to be considered whether the diggings of the whole are of the garden is necessary. The roots of the pepper plant do not appear to go beyond 2½ to 3 feet. Hence it looks as if a scraping to remove the weeds and a light digging round the plants, without damaging the root system will serve the purpose. In Travancore most of the planters give only a clean weeding to the whole area and practise 'ring cultivation' round the plants. The yield in Travancore does not seem to be less, in any way than the yield obtained in Malabar. Till experiments on these aspects are conducted it is not possible to advocate any system of inter-cultivation.

In Travancore some planters make mounds of broken stone round the base of the pepper vine instead of terracing. The weeds are removed and wherever cattle manure is available it is applied with green leaf near the base of the vines.

Tying of vines

This operation is done regularly during the first three to four years, but when once the vines establish themselves on the standards, its continuance becomes unnecessary especially for the vines growing on *Erythrina* standards. This is due to the fact that the production of vegetative branches is reduced and more flowering branches are formed. The fibrous bark of a common creeper called *chowla* (*Helicteres isora*) found in the scrub jungles of Malabar is commonly used for tying the vines, but sometimes small sized coir ropes are also used.

In Travancore some of the varieties under cultivation appear to be better climbers than the common varieties of Malabar and the tying of vines is done only for the first three years but when once they get themselves established on the standards, no further tying is done. In Malabar this operation is a regular item every year.

Regulation of shade

The pepper plant requires shade as too much exposure of the young vines to the hot sun is found to have a deleterious effect. At the same time if the vines do not get sufficient sunshine, the flowering is affected and poor setting results. So the regulation of shade is an important aspect and should be attended to regularly. As a rule the standard which supports the vine provides the necessary shade. While lateral shade is necessary, the top shade during the rainy seasons should not be too heavy and has to be regulated. This is done by judicious lopping of the standards. These standards should be such that they retain the leaves during the hot weather and put forth new leaves with the commencement of the monsoon in June-July. In this way the vines will get enough shade during the hot weather months of March to May, and the lopping, if done soon after monsoon sets in, will provide sufficient sunlight for the flushing and subsequent formation of berries. This is a complicated problem and experiments should be conducted to see the best method of regulating the shade and also to know the optimum shade and light requirements of the pepper plant.

Mulching

This is done regularly in March for all the newly-planted vines for the first 2 to 3 years, but later this practice is adopted in the case of young vines which are too much exposed to the sun. Experiments at the Agricultural Research Station, Taliparamba, show that mere mulching of the soil round the vines has increased the yield of pepper.

CULTIVATION EXPENSES

According to the Malabar system the initial cost of laying out a garden and planting the vines is rather heavy. The selected site has to be cleared of all weeds, scrub jungle, trees and old stumps. Then pits at the rate of 1,000 per 3 acres have to be dug and standards planted before the planting of vines. The average cost per acre comes to Rs. 160 to Rs. 170 (as per details furnished in Table VII below).

Recurring expenses

Unlike other garden crops on the West Coast, pepper requires continuous attention and care. The pepper garden should be cultivated regularly every year as otherwise the land will be outgrown with weeds and jungle growth. Besides the yield being reduced, such a course would ruin the plantation permanently. So whether the cultivator gets a good crop or a fair price for his produce, he cannot afford to neglect his gardens. So long as there was a good price for pepper every thing went on well, but with the depression during the years 1931-1941 most of the ryots were in difficulties. During this period some of the gardens went out of cultivation and became derelict. When the price of pepper ruled high during 1925-1931 it gave a great impetus to pepper cultivators and people brought new lands under cultivation. In the scramble for land all kinds of land were selected, without due regard to their suitability. Pepper prospecting received a rude shock when the price of pepper suddenly dropped in 1931 and not only did expansion on any large scale stop, but also some of the newly-planted gardens were abandoned.

TABLE VII

Statement showing cost of raising 1,000 vines in 3 acres in Malabar and South Kanara

First year

	Rs.	as.	p.
1 Clearing of old stumps—200 men at 8 annas	100	0	0
2 Transporting 1,000 standards and planting—100 men at 8 annas	50	0	0
3 Wages for coiling and cutting the vines—20 men at 8 annas	10	0	0
4 Planting pepper cuttings—20 men at 8 annas	10	0	0
5 First digging –100 men at 8 annas	50	0	0
6 Second digging—50 men at 8 annas	25	0	0
7 Tying of vines—10 men at 8 annas	5	0	0
8 Mulching—25 men at 8 annas	12	8	0
Total	262	8	0

Second year

	Rs.	as.	p.
1 Cleaning and digging—60 men at 8 annas	30	0	0
2 Weeding—30 men at 8 annas	15	0	0
3 Tying of vines—10 men at 8 annas	5	0	0
4 Filling up gaps—20 men at 8 annas	10	0	0
Total	60	0	0

Third year

	Rs.	as.	p.
Same as second year *plus* 10 men for lopping the side branches of standards (item 4 excepted).	55	0	0

Fourth year

Same as third year	55	0	0

Fifth year

Same as second year (item 4 excepted) *plus* 30 men for lopping branches of the standards.	65	0	0

First year .	262	8	0
Second year .	60	0	0
Third year .	55	0	0
Fourth year .	55	0	0
Fifth year .	65	0	0
Grand total .	497	8	0

Cost per year is Rs. 166 to Rs. 170 per acre

Recurring expenses

	Rs.	as.	p.
The cost of recurring expenses for 3 acres is	65	0	0
The cost of recurring expenses for 1 acre	22	0	0

Cost of bringing one acre of land of pepper under cultivation in Travancore (pure pepper plantations)

1 Clearing undergrowth and over-crowded trees and burning	20	0	0
2 Digging pits 1½ ft. × 1½ ft. × 1½ ft. at Rs. 3-2-0 per 100 .	9	8	0
3 Cost of cuttings	10	0	0
4 Planting, 20 coolies	10	0	0
5 Filling up gaps, 5 men	2	8	0
6 Weeding, 20 women	5	0	0
7 Mulching and shading	13	0	0
Total .	70	0	0

Second year

1	Digging 10 ft. round the vine and levelling square and 1½ ft. deep	75	0	0
2	Lowering of vines, 20 men	10	0	0
3	Weeding, 40 women	10	0	0
4	Lopping	5	0	0
5	Mulching and shading	13	0	0
6	Fillin g up gaps	2	8	0
	Total	115	8	0

Third year

1	Weeding, 40 women	10	0	0
2	Digging round the vines, 30 men	15	0	0
3	Lopping, 10 men	5	0	0
4	Mulching, 20 men	10	0	0
	Total	40	0	0

Fourth and fifth years

Same as third year	80	0	0
First year	70	0	0
Second year	115	8	0
Third year	40	0	0
Fourth year	40	0	0
Fifth year	40	0	0
Grand total	305	8	0

Comparative statement showing the cost of cultivation of one acre (pepper) during 1938-39 and 1943-44

	1938-39 Rs. as. p.	1943-44 Rs. as. p.
1 Digging round vines in May to June—10 vines for coolie, 30 coolies per acre	7 8 0	22 8 0
2 Mulching in October-November, 20 vines per man	3 12 0	11 4 0
3 Weedings (two) at the rate of 20 women for one weeding	5 0 0	10 0 0
4 Cost of harvesting and drying produce from one acre	13 8 0	39 0 0
5 Lopping of branches	2 4 0	6 0 0
Total	32 0 0	89 4 0 or 90 0 0

NOTE.—Rate of wages in 1938-39.—A man 4 annas and a woman coolie 2 annas.
Rate of wages in 1943-44.—A man 12 annas and a woman coolie 4 annas.
Number of vines per acre assumed to be 300.

DISEASES AND PESTS

Diseases of pepper in other countries

The diseases of pepper that have been recorded are not many and the following are some of them :

(1) *Black fruit,* caused by *Cephaleuros mycoidea* is a very serious disease of pepper in Sarawak. "The fruiting spikes set normally but after a time, the berries at the free end turn black, shrivel and some fall off. At this state the remaindor of the practically ripe berries will show small black spots, which under a hand lens, show minute golden tufts typical of *Cephaleuros mycoidea.* The disease progresses and the berries about the middle of the spiko shrivel and turn black. In the final stages the whole of the berries on the spike is involved, most fall to the ground but usually a few mummified berries still remain attached to the blackened spikes." [Sharples, 1922].

(2) Another disease of pepper has been recorded from Sarawak and has also been noticed in Singapore. 'The pepper spike while still green and unripe, show at first a yellowing on some of the fruits. These instead of becoming deeper green, eventually, become dry and quite black, the whole interior becoming black and powdery. Then on the outside of the pepper appear small black processes the fruit of the fungus. As a rule only a few of the fruits on the spiko are affected and these generally in the middle of the spike. The fruit spike is thus spoiled and generally falls off before it is fit togather.' This is said to be caused by a species of *Colletotrichum* which has been named by Mr. Massee as *Colletorichum necator.*

(3) Pepper (*Piper nigrum*) suffered from an obscure die-back of the branches in Atjeh and it was affected by a disturbance in which the fruit bearing shoots were replaced without apparent cause by those producing nothing but leaves [Leafmans, 1933].

The Phytophthora foot-rot of pepper (Piper nigrum) in the Dutch East Indies

(4) Since 1928 foot-rot of pepper has assumed major importance in the most of the cultivation centres in Sumatra, Java and Borneo. In some districts the ravages of the disease have necessitated the abandonment of the crop. 'Infection usually begins on the stems at a height of up to 30 c.m. from the base, and on non-suberized stems the diseased cortex rapidly turns from dark watery green to black, but no external symptoms are apparent on cork covered bark. The soft parenchymatous tissues of the cortex and medullary rays quickly decay, while the xylem remains intact, apart from a slight brownish discolouration. The affected bark often peels off and the central cylinder splits into a bundle of loose xylem vessels due to the rotting of the connecting tissues. The leaves turn yellow, wilt and drop, or in dry hot weather they may blacken and adhere to the plants. Most of the roots of the wilting plants are still normal but foot-rot symptoms begin at the base and progress towards the root tips. During the period of active spread of the disease, somewhat inconspicious greyish-brown spots up to 5 cm. in diameter are formed near the tips and margins of the lower leaves, and the lesions are surrounded by a zone, 3 to 5 m.m. in width of water, dark green tissues from the under side of which drops of a yellowish fluid are exuded. Both the leaf surfaces of pepper are readily infected by the mycelium and conidia of the *Phytophthora*, the zoospores of which can only attack the undersides. The typical lesions develop in two to three days, and during the night conidia are formed in profusion on the lower leaf surfaces. Diseased leaves are shed before the fungus reached the petioles.

The chief sources of infection by *P. palmivora* var. *piperis* are contaminated water, soil and diseased plant refuse. Transport by water seems to be the chief mode of conveyance of the fungus, which is almost destructive in well cultivated gardens. Experiments have shown that the foot-rot of pepper may be partially controlled by fortnightly applications of 1 per cent Bordeaux mixture. In order to minimize the risk of soil infection a net work of shallow drain trenches should be dug, with catch pits at intervals, to prevent the rain water from running off over the soil surface. When infection occurs in one of the squares, isolated by the trenches, the soil and the diseased plants should be watered with 5 to 10 litres of 1 per cent copper sulphate solution, per square meter and weeding should be temporarily discontinued to prevent the transmission of the fungus by implements or by labourers' feet or by similar means' [Muller, H.R.A. 1937].

Anthracnose of black pepper (Piper nigrum)

(5) Anthracnose is a minor disease of black pepper. It attacks the foliage and produces dead areas which interfere with the function of leaves. In the early stage of the disease the lesions are small and dark grey, irregular in size and shape, and have a distinct border. In the advanced stage the lesions enlarge and merge together forming large dead areas. The mycelium of the fungus is septate, coarse hyaline and granular in contents, either simple or branched and $15 \cdot 7 \times 6 \cdot 1$ μ. The conidiophores are simple, hyaline, granular, non-septate and $98 \cdot 0 \times 4 \cdot 3$ μ. Each conidiophore produces 2 to 6 or more conidia at the tip. The conidia are thin-walled, rounded at the end, oblong, elliptical, hyaline with granular contents,

easily detached from the conidiophores and 15·7 × 5·2 μ. In masses the spores are pinkish but become dark or almost black with age. The fungus is referred to the species *Glomerella cingulata*, S. and V.S., but it produces only the imperfect stage. The spores of the fungus are disseminated perhaps by wind, rain or water passing over the infected areas of the leaves. Under climatic conditions in the Phillipines, the fungus can remain in the form of dormant mycelium in the infected host tissues during dry weather. Rainy days favour spore germination and penetration of the host. Young and tender leaves and sun-scalded and sun-burned areas are readily infected by the causal fungus. The disease may be controlled, by collecting and burning the infected leaves ' [Vinukatanandara *et al*, 1930].

Diseases of pepper in India—(1) *Root disease or ' wilt ' diseases*

From the official records it can be gathered that the attention of the Madras Agricultural Department was directed towards a study of the pepper crop consequent on alarming and urgent appeals by the South Wynaad Planters' Association to the Government for help in combating a serious ' wilt ' disease which was taking a heavy toll in their plantations as early as 1902. In response to this appeal, Dr C. A. Barber, the then Government Botanist, visited the areas. His inspection revealed that in these areas the practice of heaping up soil to form a mound round the base of the vines was prevalent. This induced formation of superficial fibrous roots which permeated the soil in the mound in addition to the normal root system. Barber made the interesting observation that in all diseased vines the surface roots were the first to rot and perish while they remained healthy and persistent in the normal vines. In 1904 Dr E. J. Butler, the Imperial Mycologist, made a tour of inspection of the affected areas, where he found several plantations virtually depleted of vines by the wilt disease. He found that vines in exposed situations more readily succumbed to disease than those under shady conditions. He arrived at the conclusion that *Nectria* sp. was responsible for the disease. Perithecia of this fungus were found in large numbers at the base of the stem of the diseased vines. He compared this problem to the wilt of pigeon pea (*Cajanus cajan*) caused by *Fusarium udum*. At that time perithecia of *Neocosmospora vasinfecta* had been observed on the stem of diseased pigeon pea plants and this fungus was presumed to represent the perfect stage of the organism causing the wilt of the pigeon pea.

Stump rot

(2) Butler further found evidences of the existence of stump rot in pepper in Mysore caused by *Rosellinia bunodes*. Diseased patches were observed in some of the plantations where, besides the pepper vines, the standard trees and a variety of undergrowth had been killed by this fungus. In pepper the death of the vines was rather sudden ; the leaves turned yellow and soon the vines became defoliated and the stem dried up.

' Pollu '

(3) Since then, no sustained investigation has been conducted on this problem and though the disease has made a sporadic appearance in later years it has not been reported to have assumed dangerous proportions. But about the year 1918 the pepper crop again attracted the attention of the plant pathologist, but this

time it was another disease locally known as *pollu* (meaning hollow or light). On account of this disease, a varying percentage of the yield of vines was found to consist of hollow or light berries. The problem was first investigated by the Government Entomologist, Madras, and in later years jointly by the Government Mycologist and the Government Entomologist. The results of these investigations were published from time to time (1926, 1939). The conclusions arrived at, show that *pollu* (hollow berry) is attributable to three main causes, viz., (1) A fungus (*Collectotrichum* sp.), (2) A flea beetle (*Logitarsus nigripennis*), (3) Premature spike shedding. Of these *Colletotrichum* sp. has been found to be responsible for causing shrinkage and drying up of individual berries and to a small extent infection of the stalks of spikes. Further the same fungus causes spots in leaves and sometimes infect the stem causing the death of young vines or fruiting branches.

The second cause of *pollu* is insect damage. Two insects have been found responsible for damage to berries, a flea beetle commonly known as pollu beetle (*L. nigripennis*) and a gall-fly. The latter is only a minor pest but the former causes serious damage. By far the major portion of what is known as *pollu* in the trade is caused by premature shedding of spikes. The cause of spike fall has not been determined but experienced growers attribute it to either paucity or excess of rainfall. The following Table gives data collected in 1932 at the Agricultural Research Station, Taliparamba, which bring out the relative importance of spike fall, insect and fungus attack on the causation of loss by *pollu* [Thomas and Krishna Menon, 1939].

TABLE VIII

Showing the relative importance of spike fall, fungus and insect attack

Variety	Percentage of loss by spike fall	Percentage of loss by fungus	Percentage of loss by insects
1 *Balamcotta*	46·3	5·6	9·2
2 *Kalluvalli*	37·9	6·1	13·7

Diseases observed during the survey—root-rot

Root-rot (wilt) was in evidence to a small extent in all the tracts visited. In no place was the disease found to be prevalent in an alarming extent or intensity. Information gathered from the growers goes to show that this disease is not of the same intensity in all years. It usually exists in a sporadic form, involving 2 to 10 per cent of the vines of the plantations. Owing to the vicissitudes through which the industry has passed, the fluctuations in the price of pepper and consequent neglect of the gardens during slump seasons, the low percentage of mortality among the vines has seldom upset the equanimity of the growers. But it is reported that during certain years a much higher percentage of deaths occurs but the losses never attained the level it reached in the early years of this century. Among the tracts surveyed, a higher incidence was still in evidence in Wynaad, Coorg and Travancore.

The dead and dying vines observed in different tracts were carefully examined. In all cases fungi were noticed in the tissues of the roots and base of the stems. small bits of tissue from the interior of the roots and stems of the dying vines were transferred to agar media and several fungi have been isolated. Two fungi were constant factors. These sre *Diplodia* sp. and *Rhizoctonia solani*.

TABLE IX

The fungi isolated from different localities

Serial number and tract	Locality	Portions from which obtained	Fungus	Percentage of incidence
1. Wynaad	Chundale	Roots	1 *Diplodia* sp. 2 *Rhizoctonia solani* 3 *Fusarium*.	5—10
2. do.	Kalpetta	do.	1 *Diplodia* sp. 2 *R. solani*. 3 *Fusarium*	5
3. Travancore	Kanjirapally	do.	1 *Diplodia* sp. 2 *R. solani*	5
4. do.	Todupuzha	do.	1 *Diplodia* sp. 2 *R. solani* 3 *Pythium* sp.	5—10
5. S. Malabar	Manarghat	do.	1 *Diplodia* sp. 2 *R. solani*	2
6. do.	Chalasseri	do.	1 *Diplodia* sp.	2
7. Cochin State	Kunnamkulam	do.	1 *Diplodia* sp.	2
8. Mysore	Balehonnur	do.	1 *Diplodia* sp. 2 *Fusarium*	2
9. do.	Telagupa	do.	1 *Diplodia* sp.	2
10. North Kanara	Malvalli	do.	1 *Diplodia* sp.	2
11. Coorg	Pollibetta	do.	1 *Diplodia* sp. 2 *R. solani* 3 *Bacteria*	5—10
12. do.	Ammatti	do.	1 *Diplodia* sp.	5

The constancy with which *Diplodia* sp. and *Rhizoctonia solani* appear among the various isolations leads one to suspect that these might have a leading role to the causation of the disease. Species of *Diplodia* and *Botryodiplodia* have a very wide distribution in the tropical belt and have a reputation of causing root-rots of a number of perennial plantation crops like citrus, cacao, tea, coffee and para rubber. Though it is not possible to assert anything without experimental proof, it may be assumed from the frequency with which this fungus was isolated from all over the pepper tracts, that it may be one of the parasites or at least assumes the role of a parasite under certain predisposing conditions.

Next in frequency of occurrence was *Rhizoctonia solani*. This fungus was isolated from areas as far apart as South Travancore and Wynaad (Malabar). This organism is also known to attack roots of a variety of crop plants and cause ' damping off ' and wilt diseases.

Colletotrichum sp. was also isolated from diseased vines (stem) obtained from Chundale (Wynaad). This fungus is already known to infect the stem, leaves, spikes and berries of pepper.

From Travancore one isolation of *Pythium* sp. has been obtained, yet it is an important record of a notorious genus of root-rotting fungi. Outside India, *Phytophthora* has been found to be causing wilt of pepper in Malaya. It is equally possible that *Pythium* is also responsible for wilts, and the warm humid climatic conditions of the pepper areas are eminently suited for this genus.

Though it is not possible to fix the responsibility for the causation of ' wilt ' on any one of these it is just possible that each one of these is capable of producing root rot and wilt of pepper, and this is a point which required further investigation.

Properly controlled infection experiments alone can decide the question. Besides these fungi, in Coorg an insect was noticed on most of the dead vines and it is possible that this also may be one of the agents causing death of vines. Tunnels are made in the stem and pupae present inside these.

Pollu

During the survey it was noticed that wherever mature spikes were present only a low percentage of ' fungus pollu ' occurred. Collections of these diseased spikes from different localities were examined and in all cases the same fungus was observed. All isolations have produced growths of *Colletotrichum* in culture. It can be seen that this fungus enjoys a very wide distribution all over the pepper growing tracts of South India.

The fungus infects berries. The affected berries show in the early stages water-soaked brown sunken areas, and gradually the discolouration apreads over the entire berry and to a few berries on either side. Usually the discoloured berries occur in groups of two to five in number. In later stages the berries may split and acervuli of the fungus develop on the surface. Specimens obtained from Dubary Estate,

Pollibetta, Coorg, exhibited a greater amount of damage caused by the fungus. The spikes are infected at the distal ends exhibiting blackening and drying. The injury extends towards the base and involves some of the berries also. Sometimes half the spike may be involved.

During the time of the visit, viz., September-October, the infection had just commenced in these areas and it was not possible to estimate the extent of damage. But the occurrence of the same fungus all over the pepper growing areas suggests that it is a source of potential danger. Information elicited from the growers also show that the intensity of *pollu* is not of the same order in all years but varies very much from season to season. It was also reported that the loss from *pollu* was most frequent in a distinct contiguous tract extending from North Malabar to South Kanara. In this tract a greater percentage of loss is due to premature spike shedding. In some years it is reported that *pollu* cause a loss of nearly 30 per cent of the produce. It must also be remembered that *Balamcotta* is the major variety under cultivation in this tract. Records of the study of the *pollu* problem made by the Madras Agricultural Department (1926-1939) have shown that spike fall is heavier in *Balamcotta* and this may be one of the reasons for the heavier incidence of *pollu* in this tract. Spike shedding like boll shedding in cotton and button shedding in coconuts may be largely caused by disturbances in water relations of the pepper plant, but is to some extent due to the parasitic organism, *Colletotrichum* sp. affecting the stalk of the spike. This is an aspect of the problem which has to be investigated by suitable experimentation.

TABLE X

Showing the distribution of Colletotrichum sp.

Number	Tract	Locality	Parts of plants found affected
1	South Kanara	Kanhangad	Leaf
2	Malabar	Taliparamba	Leaf and berries
3	do.	Payyanur	do.
4	do.	Iritty	do.
5	do.	Mattanur	Leaf
6	do.	Wynaad	do.
7	do.	Kalpetta	do.
8	do.	Manantoddy	do.
9	do.	Manarghat	do.
10	do.	Chalasseri	do.
11	Cochin State	Kunhamkulam	Leaf and berries
12	do.	Vaniampara	Leaf
13	do.	Ollukara	Leaf and barries
14	Mysore	Balehonnur	
15	do.	Talagupa	Leaf
16	do.	Sagar	do.
17	North Kanara	Sirsi	do.
18	Coorg	Sidapur	do.
19	do.	Ammatti	do.
20	do.	Pollibetta (Dubary Estate)	Leaf berries and tip of spikes

TABLE XI

Showing the effect of the aspect of hill slope on the incidence of pollu. *Chirakkal Taluk*

Situation	Percentage of diseased tips	Number of berries		Percentage of *Pollu*	Weight of berries		Variety of pepper
		Healthy	*Pollu*		Healthy	*Pollu*	
A. Northern slope .	18	1,426	501	26	$9\frac{1}{2}$	$1\frac{7}{8}$	Balamcotta
B. do. . .	14	1,519	564	27	$10\frac{1}{2}$	$2\frac{1}{2}$	do.
C. do. . .	14	1,684	528	24	11	$2\frac{1}{4}$	do.
D. Southern slope .	6	2,082	131	6	21	$\frac{1}{2}$	do.
E. do. . .	2	2,021	63	3	21	$\frac{1}{4}$	do.

It will be seen from the above Table that gardens A, B and C which are situated on the northern slopes show a high percentage of *pollu* attack ; while gardens D and F which are on the southern slopes show less *pollu* damage than those which are situated on the northern slopes. This observation is in conformity with the experience of the cultivators. But it is reported that it is very difficult to get the vines established on the southern slopes. In the early growing stages there are heavy casualties and even in later stages it seems that the vines on the southern slopes are more short-lived than those on the northern slope. For the reason, experienced cultivators do not choose lands on the southern slopes.

Another interesting observation made is that there is more *pollu* in the pepper gardens in the northern portions of Chirakkal taluk than in the south. In the north, which is the main centre of pepper cultivation in Chirakkal taluk, the chief variety cultivated is *Balam cotta*. In the other pepper-growing tracts the percentage of *Pollu* damage is low. Estimations made during the survey showed that it ranged from 3 to 10 per cent only.

Spike shedding

This is characterized by abnormal shedding of apparently healthy spikes during the ripening period. Microscopic examination of such shed spikes at different periods and from different vines showed that the great majority of them did not show any evidence of either fungus, insect or bacterial attack. The berries collected from shed spikes being immature, become very light and partially hollow on drying the degree of lightness depending on the stage of maturity at which shedding occurs.

Shedding of spikes has been observed to vary in intensity from year to year. It is very heavy in some years while it is tolerable in other years. Such failure is attributed to abnormalities of weather such as prolonged drought or prolonged rainy or cloudy weather. No figures are available to correlate spike shedding either to

drought or continuous rain. It is, however, clear that the great proportion of loss to the crop is due to shedding of immature spikes. The loss from *pollu* of insect and fungus origin has never exceeded 15 per cent while spike fall from unknown causes has by itself taken toll of up to 35 to 40 per cent of the crop.

Insect pests of pepper

(1) Pepper flea beetle (*Longitarsus nigripennis*). This is the most important and specific pest of the pepper crop. It is a small shiny yellow and blue flea beetle—commonly called the pepper '*pollu beetle*'. The adult beetle makes a small circular hole in the rind of the berry, lays its eggs inside and covers it up with its excreta. The grub that hatches out, feeds on the kernel and makes the berry hollow. Attacked berries can be made out by the pale colour of individual berries and by the small hole drilled into it. The grub travels from one berry to another, a single grub eating the kernel of three or four berries before it becomes an adult. Sometimes the central part of the rachis of the spike is burrowed and eaten up by the insect. As a result the berries borne beyond the damaged portion do not develop for want of proper nourishment and become hollow and light.

Gall fly

(2) This pest is a reddish maggot of the family *Cecidomyiidae* and attacks the young berries and checks their further development. In the young stages the maggot is transparent or pale white and is found imbedded on the tender tissues of the pulp, between the kernel and the attachment of the berry to the spike. It causes the formation of a gall chamber on the tissue of the pulp and so further growth is arrested. The maggot attacks and causes swellings on the tender leaves, leaf stalks and stem.

Scale insects

(3) The pepper scale (*Lepidosaphes piperia*, G) is a small grey boat-shaped scale which is also specific on pepper, found attacking the main stem and leaves of infected vines. Badly infected vines dry up. This pest was noticed on the pepper vines in South and Central Travancore and the attacked vines were found dying.

Saissetia hemisphaerica, Tark

(4) This is a common scale insect found attacking coffee, tea, cotton and ferns. It is a serious pest of coffee in the planting districts of South India. The scale is very convex and spherical in shape, and has a chocolate brown colour. This was found attacking the stems, spikes and berries of pepper in Coorg.

Mealy bug (*Pseudococcus virgatus*, T.)

(5) The pest is found attacking leaves, stems and spikes. The vines sprayed with resin Bordeaux mixture at the Agricultural Research Station, Taliparamba

were found land attacked during the subsequent hot weather months. This was one of the reasons why Bordeaux mixture spraying against *pollu* had to be discontinued, though the spraying reduced *pollu*. It is possible that the mealy bug is kept in check by some beneficial fungi and the spraying might have destroyed those fungi.

Stem borer

(6) The stems of pepper were found attacked by a stem borer. The markings of the borer damage was noted on the stems but the grubs and adults were not seen. The stem borer damage was noted in Travancore and Coorg but was not seen in other localities. The attacked vine wilts and dries up. The trouble in Coorg plantations seems, to some extent, to be due to borer damage as most of the wilted plants showed the markings of borer damage besides the root-rot. Further investigations are necessary to assess the damage caused by root-rot fungi and the part played by the stem borer in causing the death of the pepper plant.

YIELD OF PEPPER

Normal yield of pepper

The yield of pepper is seldom consistent. Besides the variety, the age of vine and the fertility of the soil, there are other important factors which go to determine the annual yield. The extent of the dry weather period, the period of first hot weather showers (blossom showers) which assist the formation of spikes, the weather conditions during flushing and fertilization, the period and intensity of the monsoon all exert some influence on the final yield. The number of effectively bearing vines in any year varies considerably from garden to garden with the result that it is never possible to correctly forecast or estimate the yield before the actual harvest season. In every garden there is considerable individual variation among the vines. In respect of yields, the vines can, however, be roughly sorted out into three groups: (*a*) Good yielders, i.e., those which yield well except under very abnormal seasonal conditions; (*b*) fair yielders which yield well in alternate years or once in about three years; and (*c*) poor yielders which are consistently poor yielders. No attempt is made by the cultivator to replace the second and third sorts for reasons which are obvious. It takes from five to six years before any sizable yield is obtained from a newly planted vine and naturally the cultivator is reluctant to destroy the poorer vines and replace them with better strains or varieties. This is primarily due to the lack of initial knowledge on planting material and secondly the reluctance to destroy a grown up vine, however poor its performance may be. In this matter, it would be of immense assistance to the cultivator if he could be supplied with selected planting material of known qualities suitable for his tract from a central pepper research station. The Mysore Agricultural Department attempted some work in this direction at the Marathur Farm, but unfortunately the farm has since been closed down and the valuable work lost to the country.

Despite the obvious handicaps of correctly estimating the yields, an attempt is made in the following Tables to record the normal yields of pepper in the important pepper growing tracts and of well-known varieties of pepper in their natural habitat.

TABLE XII

Showing the normal yields of pepper per acre in the important pepper growing tracts

Year	Yield per acre in maunds			
	Malabar	South Kanara	Travancore	North Kanara
1st—3rd	*Nil*	*Nil.*	*Nil*	*Nil*
4th—5th	2	2	2	2
6th—7th	4	6	4	4
8th—20th	8	10	10	8
21st—25th	6	6	4	5
26th—30th	4	4	2	2

TABLE XIII

Showing the average and maximum yields in pounds per vine of the important varieties of pepper

Varieties	Wynaad		Kottayam		Chirkal		Mysore		North Kanara		Travancore		South Kanara	
	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
Balamcottah	2—3	6	1½—1	5	2	6	2	6—7	..	..	..	..	..	..
Kalluvalli	1½—2	4	½—1	6	2	6	1½—2	5—6	.	..	..	..	..	..
Karincotta	2—2½	5—6½	..	..	..	..	..	..	..	..	..	..	..	..
Cheriakodi	1½—2	4	..	..	..	..	.	.	..	..	..	.	..	..
Uthirankotta	½—2	2	..	..	..	..	..	..	.	..	..	..	..	..
Tall Balamcotta.	..	..	½—1	5—6	..	..	.	..	.	..	..	..	..	..
Molavalli	½—4	..	½—1	6	..	..	..	..	..	..	..	.	..	..
Kottavalli	..	..	..	..	..	..	.	.	..	..	..	.	1¼—2	6
Kottanadam	..	..	..	..	..	..	..	..	..	..	1½—2	6	..	..
Yoliakanjakadan	..	..	..	..	..	.	..	..	..	..	1½—2	6	..	..
Karuvilanchi	..	..	..	..	..	..	..	..	..	..	1½—2	6	..	..
Karimunda	..	..	..	..	..	..	..	..	..	..	1—2	5	..	..
Mallisara	..	..	..	..	.	..	1—1½	4	1½—2	5	..	..	..	..
Koddiga	..	..	..	..	..	..	½—1	4	1	5	..	..	..	..
Tolisure	..	..	..	..	..	..	½—1	3	1	4	..	..	..	..
Morata	..	..	..	..	..	..	7	3	½	3	..	..	..	..

THE PRICE OF PEPPER

The violent fluctuations in the price of pepper and the uncertainty of an estimable income from the pepper crop, has contributed in no small measure to the decline of the pepper industry in India. Table XIV shows that during a 20-year period between 1924 and 1943 the price has fluctuated between Rs. 15 and Rs. 112 per cwt. From 1924 to July 1925, the price ranged between Rs. 26 and Rs. 42 per cwt Since then there was a gradual increase till the peak figure of Rs. 112 per cwt. was reached in February 1928. High prices ruled till the first-half of 1930. But,

by the end of 1930 with the general world depression, the prices dropped to Rs. 30 per cwt. In 1940-41, they reached the bottom mark of Rs. 15. The price of the produce fell far below the cost of production. The plight of the pepper growers, the majority of whom are small landholders or tenant cultivators became desperate. Unlike other perennial crops which can stand some amount of neglect, pepper cannot be neglected, for the land would be overgrown with weeds and jungle growth affecting the yields permanently. The two alternatives left to the pepper grower were either the abandonment of the garden or its maintenance at a loss. Many gardens inevitably went out of cultivation during this slump period. But many cultivators preferred to keep the garden going and as a losing concern. Most of them borrowed money from pepper merchants by mortgaging their property. In most cases, the grower was forced to sell away the standing crop in advance of the harvest to the merchant who arranged the harvest. Naturally, the cultivators did not realize even the extremely uneconomical market price for his produce.

Table XIV

Showing the fluctuations in price of pepper during 20 years (1924 *to* 1943) *in rupees per hundred weight at Tellicherry*

Year	January	February	March	April	May	June	July	August	September	October	November	December
1924	27	30	26	27	26	27	26	27	28	28	29	29
1925	29	30	31	32	33	37	48	46	52	56	59	77
1926	66	67	60	66	70	75	..	65	70	55	62	61
1927	49	60	60	62	80	100	90	100	102	100	95	92
1928	100	112	108	107	108	105	104	102	103	103	85	90
1929	91	90	91	90	80	92	96	92	94	90	88	70
1930	77	87	80	72	62	62	62	56	50	45	40	31
1931	32	36	31	31	31	31	35	36	37	38	40	42
1932	39	41	40	39	38	38	37	34	34	33	28	27
1933	26	26	21	25	35	31	30	29	26	24	23	26
1934	28	27	27	28	29	29	28	30	33	38	32	33
1935	33	28	27	28	26	25	26	24	25	25	22	21
1936	19	19	22	22	21	19	18	18	18	19	20	26
1937	22	21	22	22	21	21	21	22	22	20	19	18
1938	20	20	19	19	19	18	19	18	18	18	17	18
1939	19	18	18	18	18	18	16	16	18	18	20	18
1940	16	17	16	16	15	15	15	15	16	15	15	14
1941	15	16	15	15	17	20	10	17	16	17	18	19
1942	20	22	24	32	40	36	32	35	36	50	45	47
1943	59	71	82	82	80	70	75	71	72	65	60	63

' ....the present market prices of pepper and cardamoms are below the costs of production and this position has been reached within the course of a few months following the announcement by the Export Trade Controller that exports of these species would be restricted to the level of 1940-41.

Both these crops are produced predominantly by small growers to whom they represent the only money crops possible under the climatic conditions of considerable areas of the Western Ghats and their foot-hills. Moreover, they are both ' good' money crops from the point of view of efficient land utilization in areas where faulty land utilization is fatally easy under considerable consequence to agriculturists over a far wider area than the actual pepper and cardamom districts. Therefore the economic well-being of these cultivators should be a matter of primary concern to the administrators concerned. Cardamoms and pepper had their full share of bad times which afflicted agricultural produces between the wars. Pepper prices fell in 1936 to little more than half the figure that stood at before the 1914–18 war and stayed at that level until 1941. The industry was barely able to survive such prices and would, in fact, have been completely destroyed were it not that the small holder producer fell back on his foodcrop production and contracted his cash expenditure to barest minimum.............In fact in both crops, substantial areas went out of production and in the case of pepper at least, a dead weight of surplus stocks kept the market comatose to point of extinction. '

With the invasion of Malaya and East Indies by the Japanese in 1942, the prices gradually rose and reached Rs. 82 per cwt. by March 1943. The announcement by the Export Trade Controller that the quota of export was fixed at the 1940–41 level had a sudden effect on the market. At the time of writing (June 1945) the market price is about Rs. 50 a cwt. The reasons for the sudden drop in prices were ably discussed in an editorial in *Planters' Chronicle*, dated 15th October, 1944.

From the foregoing it is apparent that in the interests of the cultivator there is the urgent need for the stabilization of the price of pepper in India. What has been effectively achieved in a commodity like coffee can be achieved in the case of pepper also. Until such stabilization of prices is achieved and the grower can look forward to a reasonable return for his labours the pepper industry would not offer the incentive which the cultivation of other crops like tea, coffee and rubber offers to the cultivators.

Collection of pepper varieties

The following varieties of pepper were collected from the different pepper growing tracts and are being grown at the Agricultural Research Station, Taliparamba, for future work.

Wynaad varieties . .	*Balamcotta ; Wynaad Kalluvalli ; Karincotta.*
Kottayam taluk . .	*Balamcotta ; Kalluvalli ; Kallu Balamcotta ; Malavalli.*

South Kanara . .	*Kottavalli.*
Travancore . . .	*Kottanadan ; Kaniakadan ; Perumkodi ; Karivilanchi ; Karivalli ; Mundi ; Munda ; Arikottanadam ; Thulakodi ; Kuthirawali ; Kumbakodi ; Chumala ; Karinthakara.*
Mysore and North Kanara	*Morata ; Mallisara ; Doddiga ; Tattisara ; Mottukara ;*

Wild varieties. Wild pepper was collected from the following places :

(1) Wynaad (Malabar), (2) Koni forest (Travancore), (3) Agumbe forest and Jog forest (Mysore), Mallalli (North Kanara). One of the wild varieties collected had spikes about 16 inches long, but setting of berries was extremely poor.

Varietal resistance

From observations made during the survey and enquiries from the cultivators it is gathered that *Kalluvalli* and *Karimcotta* can tolerate seasonal variations and diseases better than the other Malabar varieties. Among the Travancore varieties it is reported that *Karivilanchi, Valia Kaniakadam* and *Karivalli* are more hardy than the others. In Mysore, *Mallisara* and *Toddiga* withstand the variations better than the other Mysore and North Kanara varieties. It was not possible to make anything more than a cursory estimate of these factors from enquiries made of experienced growers.

Summary and conclusions

The survey has indicated the need for detailed information on a variety of problems connected with the pepper industry which would make the cultivation of pepper a remunerative enterprise which it is not at present. These problems are :

(1) Selection of existing high yielding varieties.

(2) Evolution of better varieties from the point of view of yield, regular bearing, drought resistance and resistance to pests and diseases.

(3) Improvement in cultural practices with a view to conserve moisture during dry months.

(4) Complete knowledge of the manurial requirements of the pepper plant and the method, doses and period of application.

(5) The relative merits of various standards and the proper methods of their maintenance in respect of the regulation of shade.

(6) The control of pests and diseases.

(7) Stabilization of prices.

Selection of high yielding varieties

The survey has shown that there is a wealth of genetically varying material available, but no systematic effort has been made to study their characters or their performances under similar conditions. The fact that pepper is propagated vegetatively, which affords scope for the rapid multiplication of selected material, should be taken advantage of to study the performances of all promising varieties at a central research station.

Evolution of better types

Not one of the existing varieties was produced by human effort at plant breeding. In a crop like pepper where cross pollination is the rule and hybrid progeny can be vegetatively multiplied at any stage of evolution, it should be possible to produce plants with a number of desirable characters in them. This is the work of a plant breeder.

Improvement of cultural practices

There is wide range of variation among the cultural practices followed in different tracts. A series of well laid out agronomic experiments at a central research station should furnish all the information required on this line. The points requiring elucidation are methods of planting, soil conservation, weeding, layering and regulation of shade.

Manurial requirements of pepper

The experiments at Taliparamba and Konni have shown that pepper responds to manuring. But, as mentioned in this report, the experiments have not been carried out with that degree of exactitude and precision which a crop like pepper demands by virtue of the variability in planting material, standards, shade, aspect, etc. It is therefore necessary to carry out adequately controlled manurial experiments to study the precise manurial requirements of the crop. In any scheme of research, this aspect should receive adequate attention.

Standards

There is difference of opinion about the choice of standards. Precise information is required on the most suitable species, the methods of their propagation and maintenance. The question of shade is intrinsically connected with the species of standard chosen, its feeding habits, longevity and the periodic treatment it receives.

Pests and diseases

Pepper in India suffers from a variety of pests and diseases. Root diseases are a problem by themselves but the existing knowledge about them and the measures of controlling them are woefully inadequate. From all accounts the prevention of root diseases appears far more feasible than their cure. While the direct preventive treatments are not ruled out, the modification of cultural and manurial practices and the employment of varietal resistance as a means of control appears more promising than direct methods. *Pollu* is the bane of the pepper industry in certain tracts. It is, however, a complex problem in which a fungus two insects and an apparently physiological phenomenon known as 'spike shedding' are involved. Here again experiments carried out at Taliparamba point to the limitations of direct control methods. Spike-shedding is a factor which calls for attack from the agronomic front. The apparent resistance of certain existing varieties to insect and fungus attacks can be explored with a view to evolve one or more varieties resistant to them.

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APPENDIX I

Statement showing the distribution of the annual rainfall on representative localities of pepper growing tracts.

(In inches)

	January	February	March	April	May	June	July	August	September	October	November	December	Total
Wynaad													
Kalpetta	1·22	0·11	0·56	6 06	10·17	20·22	41·36	17 25	7·82	10·27	4·77	1·65	130·46
Sultan Battery	2·85	.	0·15	5·02	6·93	15·37	20·72	10 89	8·19	9·92	4·21	1·48	80·73
Manantoddy	..		0·52	4 16	6·70	23·04	38·75	16 17	7·44	5·46	3 26	1·11	106 61
Malabar													
Taliparamba	..	.	0·06	3·85	4·95	36·31	51·35	20·23	10·17	8·28	6·02	0·10	140·32
Tellicherry	0·93	0·45	.	4·76	11·76	39·50	33·67	12·46	6·48	9·39	6·02	2·03	127 45
South Kanara													
Nileshwar	0·04	0·05	0·01	3·50	6·20	41 29	54·11	22·57	9·94	5·86	4 13	0·70	148·40
North Kanara													
Sirsi	0·03		0·44	1·69	2·31	22 28	34·37	22·59	7·73	7·11	2·00	0 23	100·78
Coorg													
Sidapur .	0·43	.	0·65	2 89	7 88	8·71	16·40	9·18	3·20	7·62	3·95	1·54	62·84
Santikoppa	0·86	.	0·27	3·87	6·63	10·61	17·43	10·77	3·92	6·46	4 63	1·37	66·82
Pollibetta	..	.	0·55	4·05	8 65	16·50	14·55	9·95	3 35	5·90	0·40	0·52	64·42
Mysore													
Thirthahalli	0·38	.		0·35	14·32	17·74	62·88	9 59	13 47	10·95	1·50	..	131·18
Travancore													
Attingal	0·48	1·20	3·03	4 75	8·55	8·50	4 95	2·80	6·27	7·32	1·93	0·35	50·13
Konni	2·00	2·50	6 75	8·20	15·77	16·10	11·11	5 76	9·88	11·46	1·50	0 35	91·88
Muvattupuzah	0·59	1·06	5·88	6·50	17 85	25 37	10·60	7·65	10·07	13·23	1·05	0·35	100·20

APPENDIX II

Table showing the area of pepper, and export in the Madras Presidency and Travancore State during the years 1933-34 *to* 1942-43

Year	Travancore*		Madras†				
	Area in acres	Export	Area in acres	Export			
				Foreign	Coastwise	Total	
1933-34 .	79,302	230,000	97,011	50,533	..†	..	†Figures not available
1934-35 .	75,901	128,200	95,745	60,681	..	..	
1935-36 .	84,270	172,580	97,981	24,939	..	..	
1936-37 .	90,911	126 680	103,924	23,326	..	..	
1937-38 .	90,388	182,740	104,081	16,148	..	..	
1938-39 .	89,325	202,840	102,819	15,237	143,343	158,580	
1939-40 .	86,367	299,220	104,384	16,037	102,598	118,635	
1940-41 .	87,261	254,260	104,112	9,395	64,156	73,551	
1941-42 .	88,263	215,400	105,019	30,275	208,560	233,835	
1942-43 .	69,159	244,300	103,255	53,531	125,997	179,528	

*Travancore. Total export. Figures kindly furnished by the Director of Food Supplies Travancore. Area (acres) Figures kindly furnished by the Director of Agriculture, Madras. Figures from the Season and Crop Reports, Madras Province.

APPENDIX III

Statement showing the chief characteristics of the common cultivated varieties of pepper

Variety	Tracts where commonly cultivated	Time of flowering	Period of harvesting	Size of leaves	Length of spikes	Percentage of dry to green pepper	Remarks
Kottanadan	South and Central Travancore	June-July	February—March	14·0×8 cm.	7·0—13·5	43	Good climber, yearly bearing and a heavy yielder. One of the best varieties
Kanaikadan	Central and North Travancore	May-June	January—February	14·0×6 cm.	7·5—16·5	42	Good climber, yearly bearing and a heavy yieldet. One of the best. Two distinct subdivisions, Valia and Cheria
Perumkodi	Central and North Travancore	May-June	January—February	13·0×7 cm.	10·5—17·5	40	Medium climber, yearly bearing and a good yielder.
Karivllanchi	South and Central Travancore	May-June	January—February	12·5× 8 cm.	6·0—14·0	36	Medium climber, yearly bearing and a good yielder, a good variety favoured by cultivators and traders. A hardy plant allied to Kalluvalli
Karivalli	Rani	May-June	December—June	16·5×10·5	11·0—19·5	40	Good climber, bears in alternate years
Mundi	North Travancre	May-June	November—December	14·0× 7·5	7·0—13·5	37	Medium climber, yearly bearing and a good yielder, a hardy and an early variety
Munda	Central North and Travancore	May-June	December—January	11·5× 7·5	6·0—14·0	36	Medium climber and a poor yielder
Arikottanadan	South and Central Travancore	May-June	January—February	15·0×11·75	7·5—14·0	36	Medium climber and a good yielder
Thulakodi	Central Travancore	Apr.-May	October—November	13·5× 8·5	6·5—12·5	34	Medium climber, yearly bearing a good yielder and an early variety

Kuthirawali	South Travancore	May-June	January—February	13·5 × 9·25	11·0—17·0	36	Medium climber, yearly bearing and a good yielder.
Kumbakodi	Central Travancore	May-June	February—March	13·5 × 9·5	8·0—14·5	34	Good climber, yearly bearing, a good yielder and a late variety
Chumala	Rani	Apr.-May	October—November	18·5 × 10·25	11·0—16·5	33	Good climber, yearly bearing and an early variety
Karinghakara	Central Travancore	May-June	December—January	12·0 × 7·0	5·5—13·0	37	Bold climber. a good yielder but bears only in alternate years
Balamcotta	Kottayam, North Malabar.	May-June	January—February	19·0 × 11·0	12·5—19·5	38	Good climber yearly bearing and a good yielder
Kalluvalli	North Malabar	May-June	January—February	17·0 × 9·1	8·5—17·0	42	Medium climber, yearly bearing and good yielder. A hardy plant
Cheriakodi	North Malabar	June-July	January—February	15·5 × 6·75	5·5—9·5	38	Medium climber, bears in alternate years
Uthirancotta	North Malabar	Apr.-May	November—December	16·25 × 8·4	10·5—19·0	38	Good climber produces vegetative runner in large numbers but a poor yielder
Karincotta	Wynaad	June-July	February—March	16·40 × 9·5	7·5—11·5	42	Good climber, yearly bearing, a good yielder and a hardy plant
Mallisara	North Kanara	June-July	January—February	17·76 × 12·0	8·0—12·0	42	Medium climber, yearly bearing and a heavy yielder
Doddiga	North Kanara	June-July	January—February	19·35 × 11·55	7·5—10·5	38	Medium climber and a uniform yielder
Mettukara	North Kanara	June-July	January—February	15·,0 × 13·0	5·0—8·0	38	Bold climber and a uniform yielder

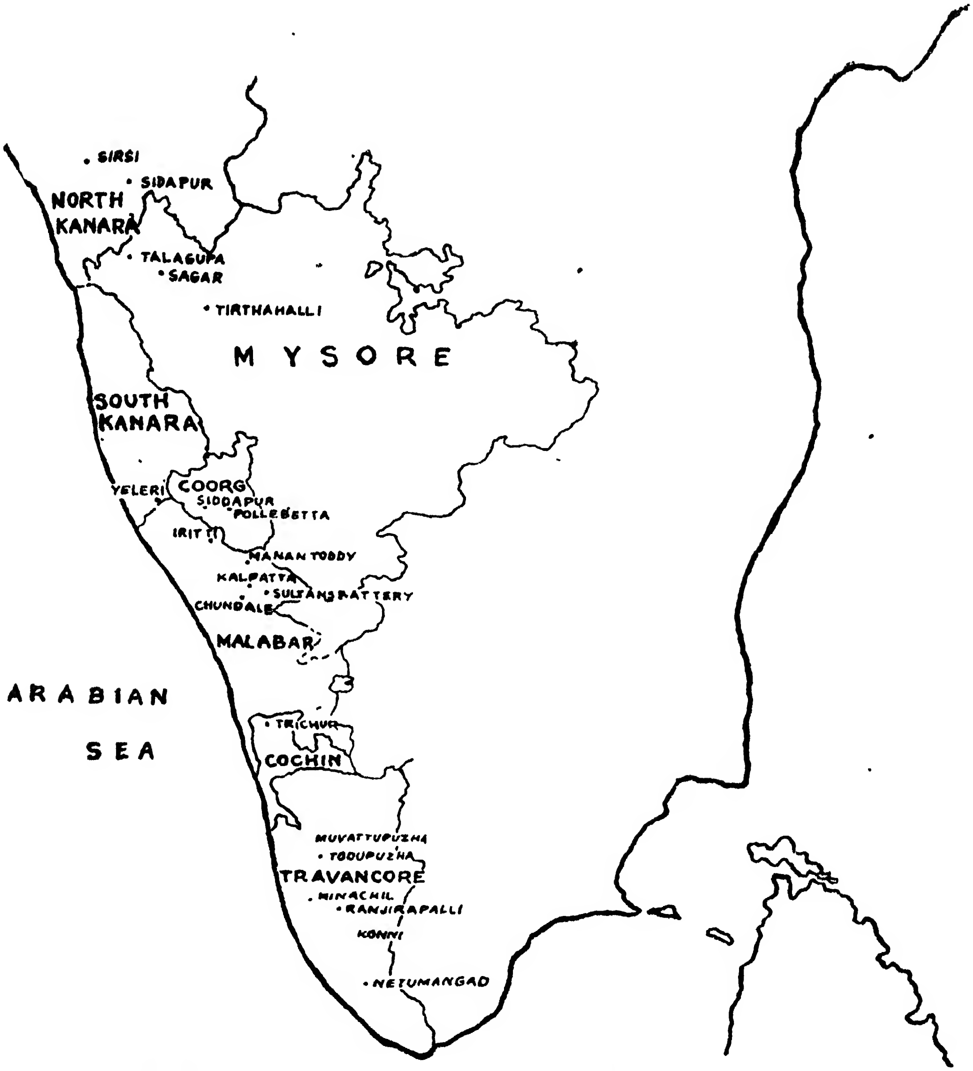
APPENDIX IV

Statement showing the soil analysis (chemical) of some of the pepper growing tracts

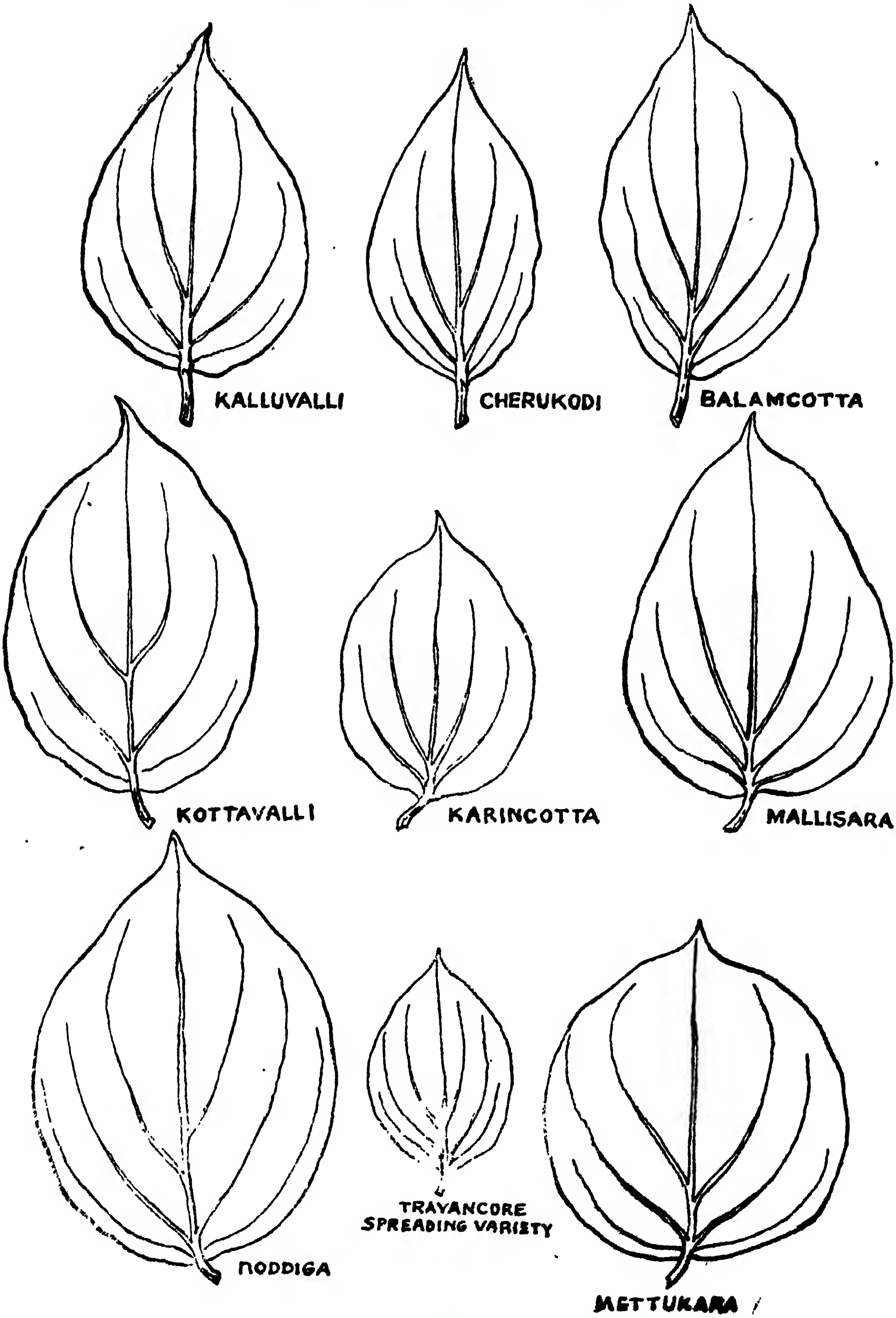
No.	Locality	Loss on ignition	F_2O_3	Cao	Mg	K_2O	P_2O_5	SO_3	N	Av.K_2O	Av. P_2
1	South Wynaad (Malabar)	11·69	18·48	0·15	0·26	0·44	0·123	0·10	0·008	0·004	0·262
2	North Wynaad (Malabar)	11·57	33·72	0·11	0·16	0·436	0·178	0·10	0·011	0·006	0·082
3	Pollibetta (Coorg)	7·30	10·79	0·33	0·10	0·20	0·17	..	0·166	0·033	0·026
4	School Estate (Coorg)	5·05	15·95	0·25	0 60	0·25	0·10	0·10	0·164	0·002	0·016
5	Sidapur (Coorg)	9·08	19·93	0·217	0·249	0·117	0·250	0·084	0·157	0·022	0·013
6	Mundakayam (Travancore)	13·00	16·68	0·028	0·077	0·365	0·112	0·084	0·165	0·019	0·021
7	Kottayam (Travancore)	12·29	22·44	0·26	0·53	0·31	0·05	0·19	0·126	0·113	Trace
8	Kadur (Mysore)	6·79	39·91	0·061	0·214	0·081	0·026	0·004	0·004	0·004	0·001

Statement showing the soil analysis (mechanical) of some of the pepper growing tracts

No.	Locality	Fine gravel	Coarse sand	Fine sand	Silt	Fine silt	Clay	Organic matter
1	South Wynaad (Malabar)	..	30·57	23·83	7·66	15·31	6·91	11·69
2	North Wynaad (Malabar)	..	17·40	17·57	10·32	21·84	18·49	11·57
3	Pollibetta (Coorg) .	7·47	29·8	31·0	6·3	8·0	12·5	7·30
4	School Estate (Coorg) .	..	26·2	29·5	5·1	12·9	19·6	5·05
5	Sidapur (Coorg) . .	1·50	18·95	38·58	4·42	17·51	18·75	9·08
6	Mundakayam (Travancore)	5·5	28·90	14·90	8·36	22·83	16·93	13·00
7	Kottayam (Travancore)	5·3	53·41	16·90	1·92	1·31	3·21	12·29
8	Kadur (Mysore) . .	..	17·00	14·55	23·12	21·56	17·54	6·79



Map showing important pepper growing tracts of South India


KALLUVALLI
CHERUKODI
BALAMCOTTA
KOTTAVALLI
KARINCOTTA
MALLISARA
MODDIGA
TRAVANCORE
SPREADING VARIETY
METTUKARA

STUDIES IN THE CLARIFICATION OF SUGARCANE JUICE IN *GUR* MANUFACTURE

By K. L. Khanna and A. S. Chacravarti, Central Sugarcane Research Station, Pusa, Bihar

THE manufacture of *gur* in India is a cottage industry of first class importance in that it accounts for over 60 per cent of the cane crop grown in the country. Being almost entirely in the hands of the small cultivator, the industry is inevitably associated with crude and inefficient methods, resulting in considerable losses in quality as well as quantity on account of which the cultivator is put to a great disadvantage. The need for improved methods has been strongly felt and attempts made from time to time to achieve progress in this direction.

Juice clarification is perhaps the most important factor in obtaining a product of high quality and is more often than not, sadly neglected. While some varieties of cane may give rise to satisfactory products without much care being bestowed on this process, it is essential with varieties giving rise to juices of poor inherent claribility to resort to some very efficacious juice treatment.

Several methods of clarification known in *gur* manufacturers' practice are mentioned in the report on the marketing of sugar in India and Burma [1943], such as the mucilaginous extract of the green stems of *deola* (*Hibiscus ficulenus*) and *bhindi* (*Hibiscus esculentus*) and the bark of *sukhlai* (*Kydia calycina*). The extract of *falsa* bark (*Grewia asiatica*) is also used, though it is not mentioned in the report. These agents, while undoubtedly promoting better quality, are not effective enough to answer the needs of poor claribility juices. Milk is also sometimes used in juice clarification but it is too expensive to be practical. Lime water or diluted milk of lime is used in some parts of the country but although lime has a binding and neutralising effect, which is particularly helpful in dealing with diseases or logged canes with high acid content, the use of this material imparts a very dark colour to the product. ' Blankit ' (sodium hydrosulphite) is some times employed with a view to bleaching and improving the colour of *gur* but the good colour of the product so obtained begins to deteriorate very fast. Further, excessive use of this chemical which is quite common, imparts an unpleasant sulphur taste. The process of treating the juice with activated carbon from paddy husk, while giving a high grade product, involves a particularly heavy cost hardly within the means of the small cane growers, apart from detracting greatly from the simplicity of the manufacturing process and considerably lowering the yield

The coagulating effect on colloids of electrolytes (acids, alkalis and salts) being well known, particularly of those giving rise to high valency ions, their application in the clarification of juice for *gur* manufacture was considered of particular interest. In these experiments [Khanna, 1945, 1946], an exhaustive study of the effect of

a number of electrolytes was undertaken, sometimes used in conjunction with the common preparation—*bhindi* mucilage. A new process of clarification was also developed and its efficiency examined in relation to other treatments, using a large number of cane varieties for comparison. The experiments were conducted over three successive seasons.

Experimental

(a) Clarification with electrolytes

The electrolytic clarifying agents were added at the rate of 20 to 25 grams per maund of juice before the boiling commenced and the scum was removed carefully as it formed. The process of manufacture was the same as is usually followed. Two varieties of cane, viz. Co 313 and Co 453 were used in the experiment. In the case of Co 313, the following electrolytes were used : (1) Sodium carbonate, (2) sodium carbonate with *bhindi* mucilage, (3) sodium bicarbonate, (4) sodium bicarbonate with *bhindi* mucilage, (5) potassium carbonate, (6) acetic acid, (7) acetic acid with *bhindi* mucilage, (8) citric acid, (9) aluminium sulphate, (10) aluminium sulphate with *bhindi* mucilage, (11) alum, (12) alum with *bhindi* mucilage, (13) caustic soda, (14) caustic soda with *bhindi* mucilage, (15) ferric chloride with *bhindi* mucilage. Treatment with *bhindi* mucilage was the basis of comparison. The undermentioned electrolytes were used with Co 453:—(1) Double Superphosphate with *bhindi* mucilage, (2) caustic soda with *bhindi* mucilage, (3) sodium carbonate (4) acetic acid. *Bhindi* mucilage treatment here was also included for comparison.

(b) Clarification by a new process

This process consists in the clarification of juice by a water extract of crushed castor seeds (*Ricinis communis*) which is prepared by grinding the seeds, taken together with some water in a mortar. The resultant milky liquid is strained through cloth and collected in a vessel to be used as the clarifying agent. The seeds are treated in the same way with further quantities of water, so long as a milky liquid continues to be formed after which the exhausted seeds are replaced by fresh ones. In treating two maunds of juice, the extract of one chhatak of castor seeds (weight including shell) is used. About half the quantity is added before boiling commences, the remaining half being gradually sprinkled on the juice during the course of boiling and the scum being carefully removed as it forms. The addition is discontinued (at a temperature of 102-103°C.) before the *rab* stage is attained.

A further simple modification in the processing technique is adopted, viz. the pan contents after strike are briskly agitated with a stirrer (rather more vigorously than usual) before the material is transferred into moulds.

The method was tested against the *bhindi* mucilage treatment with reference to a large number of varieties in the first two crushing seasons. An exactly similar extract of groundnuts was also examined in the second season and the quality of the product obtained from several varieties evaluated with respect to those of the castor seed extract and *bhindi* mucilage treatments.

In the third season, a statistically planned experiment in respect of the three treatments with four varieties (Cos 313, 383, 453 and 513) in four replications was carried out under carefully standardised conditions wherein each pan was struck at the same temperature (118°C.) recorded with precision.

Similar experiments were also conducted to ascertain the relative merits of the three treatments with reference to immature canes (early in October) and water-logged canes giving rise to juices of abnormally high colloid content (1·433 to 1·564 per cent).

A set of experiments to compare the efficacy of the castor seed and groundnut extracts with the extracts of *deola* and *falsa* bark (in common use in the United Provinces) was also performed.

(*c*) ***Evaluation of the end-product with respect to quality***

All samples of *gur* resulting from these experiments were examined in respect of general features such as hardness, texture, taste and colour. In addition, they were also analysed for the following important physical and chemical criteria—sucrose, glucose, moisture, acidity, pore space, intensity of colour of standard solutions and relative amounts of suspended impurities, as indicated by "turbidity" of standard solutions. In the experiments conducted during the third season—ash contents were also determined and Nett Rendements (=sucrose per cent—glucose per cent —3·5×ash per cent) calculated. The methods of determination have been described in a previous communication [Khanna and Chacravarti, 1949].

The observations on the various samples of *gur* prepared from the varieties Co 313 and Co 453 by the addition of different electrolytes are shown in Table I. In Table II, the results obtained during the first season with the castor seed extract treatment are shown against *bhindi* mucilage for a number of cane varieties. Table III incorporates similar data pertaining to the second season, wherein the performance of groundnut (*Arachis hypogaea*) extract is also brought out. Table IV sets out the results of the third season showing the behaviour of the three treatments in respect of four varieties in four replications. The data for immature and water-logged canes are contained in Tables V and VI respectively. Table VII provides a comparison of the castor seed and groundnut extract treatments with *deola* mucilage and *falsa* bark extract. Tables VIII to XII briefly depict the results of analysis of variance performed in respect of the different experiments of the third season stated above. Table XIII shows certain chemical features of the extracts of castor seeds, groundnuts, *bhindi*, *deola* and *falsa* bark, Table XIV the average yields of *gur* by different treatments.

Discussion of results

A reference to Table I will give an idea of the quality of *gur* obtained by means of the various juice treatments with Co 313 and Co 153. In what follows, a comparative discussion of the different clarifying agents—electrolytic and otherwise—has been undertaken so as to arrive at a correct estimate of their efficacy and select the most effective clarification process.

First considering the results with Co 313, it will be seen from the general observations that all samples are hard, crystalline and of good taste, variation being observed only in colour. The following treatments may be said to produce good colour (golden yellow or brilliant golden), the rest yielding *gur* of an undesirable (red) colour :

(1) *Bhindi* mucilage, (2) castor seed extract, (3) sodium carbonate, (4) sodium carbonate with *bhindi* mucilage, (5) sodium bicarbonate, (6) sodium bicarbonate with *bhindi* mucilage, (7) acetic acid, (8) acetic acid with *bhindi* mucilage, (9) citric acid.

A quantitative gradation in respect of the intensity of colour is available in the colour readings of 1/4 normal solutions, taken with the Photo electric colorimeter. It will be seen that a considerably lower reading is recorded with the castor seed extract treatment (55) and among the other treatments mentioned above, the values for Nos. (1), (3), (4), (5), (6) and (8) are the lowest, varying between 85 and 100. Treatments (7) and (9) show somewhat higher values 120-130. All samples other than those enumerated above, which are red in colour, record considerably higher values, varying between 130 and 200.

Differences in sucrose, glucose, moisture and acidity values are not systematic but the figures for turbidity in case of the castor seed extract treatment are distinctly lower than all others, showing the presence of the least amount of suspended impurities. This treatment, followed closely by *bhindi* mucilage is associated with the highest pore space values, i.e. open texture.

Considering these facts, it may be said that the castor seed extract treatment gives a product of outstanding quality, not approached by any other with respect to the very light and attractive shade of colour. Treatment with sodium carbonate or sodium bicarbonate either alone or with *bhindi* mucilage, also produces fairly good quality but the use of these electrolytes appears to yield no particular advantage over *bhindi* mucilage, used alone. Acetic acid or citric acid also proves fairly efficacious but are distinctly inferior to *bhindi* mucilage. All the other electrolytes examined are clearly of not any use in that they yield red coloured products when the common *bhindi* mucilage itself is capable of giving golden yellow *gur*.

Coming to Co 453, it is found that all samples are hard but none of them is quite crystalline except the product of the castor seed extract treatment, which is fairly crystalline. The taste is good in all cases except one. The colour is dark chocolate with *bhindi* mucilage and dark red with the rest with one exception, viz. for the castor seed extract, in which case the product is cream coloured. The figures for intensity of colour show a low value (95) for the castor seed extract treatment as against 200 for *bhindi* mucilage. Other clarificants showing somewhat lower values than *bhindi* mucilage are sodium carbonate (185) and ‘ Double super used with *bhindi* mucilage ’ (165) but the improvement can hardly be called substantial.

Sucrose contents are generally of the same order. With respect to glucose, moisture and acidity no appreciable differences are observed. The pore space value is the highest for the castor seed extract treatment.

In view of the very good results obtained with the castor seed extract process with the varieties Co 313 and Co 453 (particularly the latter, as it ordinarily yields very dark coloured *gur*), several other varieties were treated by this process and the

results judged against the common *bhindi* mucilage clarification process. In Table II has been included a comparison of the properties of *gur* from all these varieties prepared during the first season by the two processes. It will be seen that Co 513 like Co 313, yields brilliant golden end-product by the new process as against the rather dull golden yellow colour obtained with *bhindi* mucilage. Co 395 and B. O. 3 yield pale yellow *gur* by this method instead of the deep red stuff resulting from *bhindi* mucilage clarification and the difference is more conspicuous in these cases. It is most striking for Co 453 which yields cream coloured *gur* in contrast to the dark chocolate obtained with *bhindi* mucilage and further, the crystalline nature is distinctly enhanced in this case. A reference to the figures for colour intensity further supports the above observations.

So far as sucrose, glucose and moisture contents are concerned, there appears to be no systematic difference and this may be said of the acidities as well. Pore spaces are in most cases distinctly higher for the castor seed extract treatment, showing that the process tends to yield end-products with more open texture. Similarly, the smaller values for the turbidities of standard solutions of *gur* samples prepared by this treatment indicate smaller concentrations of suspended impurities present in them.

The data pertaining to the second season (Table III) which refer to a large number of varieties, fully corroborate the above observations. It further appears that the extract of groundnuts is as effective as that of castor seeds and possibly more so in several cases.

The data collected in the third season will be found in Table IV. These experiments were conducted with respect to four varieties in four replications (Cos 313 383, 453, 513) under carefully controlled conditions, the temperature of strike (118°C.) being recorded with precision. Analysis of variance done in respect of the different characteristics of *Gur* (*vide* Table VIII) show highly significant differences between treatments for several properties. Thus, the castor seed and groundnut extract treatments give rise to higher values for pore space (denoting a more open texture) and lower figures for colour and turbidity in standard solutions (indicating lightness of colour and smaller amounts of insoluble suspended impurities). The superiority of these two treatments over *bhindi* mucilage is thus clear. As between castor seed and groundnut extract differences are not significant but the latter shows a superior trend in respect of almost all the properties. The fact that Nett Rendement values under the different treatments are non-significant shows that none of them significantly affects refining qualities.

A comparison of the three treatments with respect to immature canes (early October) will be seen in Table V and the results of analysis of variance in Table IX. Here again, most of the values show highly significant results in favour of the castor seed and groundnut extracts and while the difference between these two is non-significant, the superiority of the latter in most cases is clearly noticeable. Nett Rendement differences are non-significant for the three treatments. The performance of the two extracts in respect of immature canes brings out their effectiveness in a difficult case.

Table VI incorporates data on water logged canes, giving rise to juices of abnormally high colloid content (1·433—1·564 per cent). The results of analysis of variance are set out in Table X. What has been said for immature canes will be seen to apply equally well here and it would thus appear that the castor seed and groundnut extract treatments adequately meet the case of juices of abnormally poor quality, ordinarily resulting in low grade products.

Tables VII, XI and XII provide a comparison of the properties of *gur* prepared by the castor seed and groundnut extract treatments with those of products resulting from treatment with the mucilages of *deola* and *falsa* bark—clarifying agents commonly used in the United Provinces. It will be seen that the colour values of the castor seed extract treatment are conspicuously lower than those under *deola* and *falsa* extracts and that the differences are highly significant. In respect of most other characters, the superiority of the castor seed extract treatment, although not statistically significant, is systematically manifested. Similar behaviour is met with in case of groundnut extract also where superiority not only in colour but in turbidity as well is highly significant. Higher pore space is also apparent in respect of this treatment. The *falsa* bark extract treatment proves systematically inferior to *deola* mucilage in respect of most characters and this conforms to general experience in the United Provinces, where *deola* mucilage is believed to be by far the more effective of the two treatments.

It can be safely concluded from the above observations that clarification by castor seed or groundnut extract is definitely superior to that obtained with *bhindi*, *deola* or *falsa* mucilage and a number of electrolytic substances. It also gives quite good results with juices of immature canes and also water logged canes, abnormally rich in colloids which normally yield inferior products. The same observation has been made with respect to canes badly damaged by termites (Colloids 1·185 per cent on juice) although the figures are not included here. It has been seen in the various statistical tables that the Nett Rendement is not adversely affected by this process. The yield of *gur* on juice is also unchanged, as shown by average data (Table XIV). The method of clarification, therefore, undoubtedly constitutes a remarkable improvement. The materials (castor seeds or groundnuts) are within easy reach of the small cane grower, involving an expenditure of hardly more than half anna or so per maund of *gur*. In view of the small quantities used, the loss by way of oil and cake (otherwise available) is negligible.

It was considered interesting to enquire into the chemical characteristics of the different organic clarifying extracts, so as to open the way for ultimately developing a universally applicable ready-made product. The materials (castor seeds, groundnuts, *bhindi* and *deola* stems and *falsa* bark) were extracted with 20 times their weight of water, filtered through cotton wool in the first two cases and strained through cloth for the rest. The preliminary determinations included, crude proteins, true proteins, ash content, P_2O_5, sol. SiO_3 and the oxides of the higher valency metals, Ca, Mg, Al and Fe. The results are expressed as milligrams of the ingredient per 100 cc. of the extract (Table XIII). The castor seed and groundnut extracts which showed outstanding clarifying power clearly possess the following characteristics :

(i) they are very much richer in crude proteins,

(ii) the same holds good for true proteins,

(iii) the ratio of true proteins to crude proteins is remarkably high,

(iv) phosphate contents are distinctly higher.

The important role of proteins and phosphate in determining clarifying properties is thus apparent. The possibility of a certain amount of adsorption of juice colloids at the liquid—liquid interface (oil-juice) cannot also be ruled out.

Summary and conclusions

The manufacture of *gur* consumes by far the greater part of the cane crop grown in the country and must therefore be regarded as a very important agricultural industry. Being almost entirely in the hands of the small cultivator, the industry is inevitably associated with crude and inefficient methods, as a result of which the product suffers greatly in quality as well as quantity. The need for improved methods is, therefore, imperative.

Juice clarification is perhaps the most important factor in obtaining good quality products but is apt to be neglected. The need for effective clarification is most pressing in case of cane varieties giving juices of poor claribility, which call for efficient clarifying treatments so as to give end-products of high quality.

In view of the well known property of electrolytes (acids, alkalis and salts) of coagulating colloidal solutions, a study of a series of electrolytes was undertaken in respect of their efficacy in juice clarification, with reference to the well known clarifying agent, *bhindi* mucilage (*Hibiscus esculentus*) as a basis of comparison. A thorough qualitative and quantitative examination of the *gur* samples prepared by different treatments in respect of general features and important physical and chemical criteria leads to the conclusion that none of the electrolytes used is capable of giving any better results than the common *bhindi* mucilage. In fact, some of the electrolytes are decidedly inferior in respect of the quality of *gur* obtained. The use of these electrolytes for juice clarification cannot, therefore, be advocated.

A novel process involving clarification with a water extract of castor seeds or groundnuts followed by a slightly modified processing technique, produced outstanding results, far surpassing the *bhindi* mucilage treatment and all the electrolytes in efficacy. It is also very much superior to *deola* and *falsa* bark extracts—clarificants in vogue in the United Provinces. The process also gives very good results with immature canes as well as juices of abnormally high colloid content, e.g. water logged or termite infested canes. The method is very cheap and pre-eminently suited to village conditions, being at the same time capable of producing high quality *gur* from juices of poor claribility. Its adoption would, therefore, prove of great benefit to the *gur* industry.

Certain chemical characteristics of castor seed and groundnut extracts are recognised which obviously induce superior clarifying power.

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TABLE I

Showing properties of Co 313 and Co 453 gur *prepared by different treatments*

Co. 313

Serial No.	Treatment	Sucrose per cent	Glucose per cent	Moisture per cent	Pore space (cc/100g)	Colour reading (N/4 solution)	Turbidity (N/4 solution)	Millieq. acid in 100 g	General observations
1	*Bhindi* mucilage	80·6	4·79	5·06	26·8	95	2·00	12·9	Hard, crystalline, taste good, colour golden yellow
2	Castor seed extract	80·4	4·79	4·78	27·0	55	1·84	12·9	Hard, crystalline, taste good, colour brilliant golden
3	Sodium carbonate	81·2	4·76	5·50	24·7	85	2·15	13·7	Hard, crystalline, taste good, colour golden yellow
4	Sodium carbonate with *bhindi* mucilage	80·4	4·27	5·48	24·5	90	2·61	10·8	Hard, crystalline, taste good, colour golden yellow
5	Sodium bicarbonate	80·4	4·77	5·24	21·3	90	2·07	13·5	Hard, crystalline, taste good, colour golden yellow
6	Sodium bicarbonate with *bhindi* mucilage	80·2	5·24	5·14	20·5	100	2·22	12·8	Hard, crystalline, taste good, colour golden yellow
7	Potassium carbonate	79·6	5·40	5·50	21·4	175	2·00	12·9	Hard, crystalline, taste good, colour red
8	Acetic acid	80·6	4·67	5·24	23·3	130	2·15	13·2	Hard, crystalline, taste good, colour golden yellow
9	Acetic acid with *bhindi* mucilage	81·0	5·09	5·50	22·2	95	2·52	15·4	Hard, crystalline, taste good, colour golden yellow
10	Citric acid	80·0	4·69	4·26	20·9	120	2·25	12·9	Hard, crystalline, taste good, colour golden yellow

TABLE I—*contd.*

Showing properties of Co 313 and Co 453 gur *prepared by different treatments*

Co 313

Serial Number	Treatment	Sucrose per cent	Glucose per cent	Moisture per cent	Pore space (cc/100g)	Colour reading	Turbidity	Millieq. acid in 100g.	General observations
						N/4 solution			
11	Aluminium sulphate	79·4	5·70	5 58	19·3	200	1·90	12·6	Hard crystalline, taste good, colour red
12	Aluminium sulphate with *bhindi* mucilage	79·4	5 69	5·96	20·0	130	2·29	15·4	Hard crystalline, taste good, colour red
13	Alum	79·0	5·12	5·46	20·5	150	2·00	12·9	Hard crystalline, taste good, colour red
14	Alum with *bhindi* mucilage	79·6	5 69	5 56	19·0	135	2·00	14·8	Hard crystalline, taste good, colour red
15	Caustic soda	80·0	5·69	5 04	18·5	145	2 17	15·4	Hard crystalline, taste good, colour red
16	Caustic soda with *bhindi* mucilage	78·6	5·15	5 84	19·5	155	1·97	13·0	Hard crystalline, taste good, colour red
17	Ferric chloride with *bhindi* mucilage	80·6	5·12	5 32	22·8	140	2·20	15·4	Hard crystalline, taste good, colour red

Co 453

Serial Number	Treatment	Sucrose per cent	Glucose per cent	Moisture per cent	Pore space (cc/100g)	Colour reading	Turbidity	Millieq. acid in 100g.	General observations
18	*Bhindi* mucilage	80·4	6 42	5·16	21·2	200	2·25	14·8	Hard, not quite crystalline, taste good, colour dark chocolate
19	Castor seed extract	80·4	5·31	5 18	22·1	95	2·04	14·8	Hard, fairly crystalline, taste good, colour cream
20	Double super with *bhindi* mucilage	80 4	5 92	5·66	21·9	165	2·12	14 8	Hard, not quite crystalline, taste good, colour dark red
21	Caustic soda with *bhindi* mucilage	78·2	5·49	5·16	18 5	240	1·50	15·4	Hard, not quite crystalline, taste fair, colour dark red
22	Sodium carbonate	80·0	4·40	5·66	19·4	185	2·02	15·4	Hard, not quite crystalline, taste good, colour dark red
23	Acetic acid	80·4	5·12	5·64	18·9	200	1·72	14·2	Hard, not quite crystalline, taste good, colour dark red

TABLE II

Showing a comparison of the properties of gur *from different varieties prepared by the castor seed extract and* bhindi *mucilage treatments : Season 1945-46*

Serial Number.	Variety	Treatment	Sucrose per cent	Glucose per cent	Moisture per cent	Pore space (cc./100g)	Colour reading	Turbidity	Milli eq. acid in 100 g	General observations
							N/4 solution			
1	Co 313	*Bhindi* mucilage	80·6	4·79	5·06	26·8	95	2·00	12·9	Hard, crystalline, taste good, eolour, golden yellow
2	Co 313	Castor seed extract	80·4	4·79	4·78	27·0	55	1·84	12·9	Hard, crystalline, taste good, colour brilliant golden
3	Co 453	*Bhindi* mucilage	80·4	6·42	5·16	21·2	200	2·25	14·8	Hard, not quite crystalline, taste good, colour dark chocolate
4	Co 453	Castor seed extract	80·4	5·31	5·18	22·1	95	2·04	14·8	Hard, fairly crystalline, taste good, colour cream
5	Co 395	*Bhindi* mucilage	79 4	4·81	5·12	17·5	160	2·23	13·3	Hard, crystalline taste, good, colour deep red
6	Co 395	Castor seed extract	79·8	4·79	4·90	20·8	85	2·00	13·3	Hard, crystalline taste, good, colour pale yellow
7	Co 513	*Bhindi* mucilage	80·8	4·79	4·96	27·0	100	1·95	13·3	Hard, crystalline, taste good, colour golden yellow
8	Co 513	Castor seed extract	80·6	4·81	5·04	27·5	60	1·90	12·9	Hard, crystalline, taste good, colour brilliant golden
9	B.O. 3	*Bhindi* mucilage	74·8	5·31	7·92	20·3	150	2·10	13·3	Hard, crystalline, taste good, colour deep red
10	B.O. 3	Castor seed extract	74·8	4·81	5·06	22·7	80	2·02	13·3	Hard, crystalline, taste good, colour pale yellow

TABLE III

A comparison of the properties of gur *from different varieties prepared by the castor seed and groundnut extracts with* bhindi *mucilage treatment : Season 1946-47*

Serial Number.	Variety	Treatment	Sucrose per cent	Glucose per cent	Moisture per cent	Pore space (cc/100g)	Colour reading (N/4 solution)	Turbidity (N/4 solution)	Milli eq. acid in 100g	General observations
1	Co 313	*Bhindi* mucilage	79·8	5·13	4·70	23·4	97	2·04	13·3	Hard, crystalline, taste good, colour golden yellow
2	Co 313	Castor seed extract	80·2	5·00	4·64	25·1	53	1·85	13·3	Hard, crystalline, taste good, colour brilliant golden
3	Co 313	Groundnut extract	82·6	5·00	3·84	27·3	48	1·97	12·9	Hard, crystalline, taste good, colour brilliant golden
4	Co 383	*Bhindi* mucilage	81·2	6·41	3·10	11·2	160	2·03	14·8	Hard, crystalline, taste good, colour deep red
5	Co 383	Castor seed extract	82·8	7·70	2·80	21·9	90	1·94	14·8	Hard, crystalline, taste good, colour light whitish yellow
6	Co 395	*Bhindi* mucilage	82·0	6·70	3·74	8·0	165	2·04	15·2	Hard, crystalline, taste good, colour deep red
7	Co 395	Castor seed extract	83·0	5·92	3·54	16·8	97	1·95	14·8	Hard, crystalline, taste good, colour pale yellow
8	Co 453	*Bhindi* mucilage	77·0	10·27	6·54	11·8	260	2·17	16·8	Hard, not quite crystaline, taste good, colour dark chocolate.
9	Co 453	Castor seed extract	81·6	7·33	5·86	19·5	90	2·02	14·8	Hard, crystalline, taste good, colour light cream

TABLE III—contd.

A comparison of the properties of gur *from different varieties prepared by the castor seed and groundnut extracts* bhindi *with mucilage treatment : Season 1946-47*—contd.

Serial Number	Variety	Treatment	Sucrose per cent	Glucose per cent	Moisture per cent	Pore space (cc) (100g)	Colour reading	Turbidity	Milli eq. acid in 100g	General observations
							N/4 solution			
10	Co 453	Groundnut extract	81·4	7·00	5·24	19·4	90	1·96	14·8	Hard, crystalline, taste good, colour light cream
11	Co 508	*Bhindi* mucilage .	78·0	5·50	5·60	18·1	100	2·00	13·8	Hard, crystalline, taste good, colour golden yellow
12	Co 508	Castor seed extract	78·2	5·30	4·00	21·5	56	1·91	12·5	Hard, crystalline, taste good, colour brilliant golden
13	Co 508	Groundnut extract	78·6	5·13	4·70	24·4	50	1·92	12·5	Hard, crystalline, taste good, colour brilliant golden
14	Co 513	*Bhindi* mucilage .	77·0	5·30	5·04	23·1	96	2·05	12·5	Hard, crystalline, taste good, colour golden yellow
15	Co 513	Castor seed extract	80·2	5·00	5·30	24·8	55	1·90	12·9	Hard, crystalline, taste good, colour brilliant golden
16	Co 513	Groundnut extract	77·0	5·30	5·68	23·6	50	1·90	12·9	Hard, crystalline, taste good, colour brilliant golden
17	B.O. 3	*Bhindi* mucilage .	79·2	8·56	4·98	9·1	152	1·97	15·8	Hard, crystalline, taste good, colour deep red
18	B.O. 3	Castor seed extract	79·2	6·41	2·90	18·0	84	1·90	14·8	Hard, crystalline, taste good, colour pale yellow
19	B.O. 3	Groundnut extract	80·2	6·16	3·18	19·2	80	1·93	14·4	Hard, crystalline, taste good, colour whitish yellow

20	B.O. 10	*Bhindi* mucilage .	79·4	7·33	2·86	7·1	180	2·00	16·4	Hard, crystalline, taste good, colour deep red
21	B.O. 10	Castor seed extract	81·2	5·92	3·10	21·0	100	1·95	14·8	Hard, crystalline, taste good, colour pale yellow
22	B.O. 11	*Bhindi* mucilage .	82·8	6·70	4·22	15·9	175	2·00	14·8	Hard, crystalline, taste good, colour deep red
23	B.O. 11	Castor seed extract	82·4	5·31	2·96	31·4	100	1·90	14·8	Hard, crystalline, taste good, colour pale yellow
24	B.O. 15	*Bhindi* mucilage .	78·0	7·00	4·54	16·9	185	2·05	15·3	Hard, crystalline, taste good, colour deep red
25	B.O. 15	Castor seed extract	81·2	4·40	4·50	23·6	105	1·90	14·8	Hard, crystalline, taste good, colour pale yellow
26	B.O. 21	*Bhindi* mucilage .	80·8	5·92	4·90	16·6	180	2·00	15·8	Hard, crystalline, taste good, colour deep red
27	B.O. 21	Castor seed extract	82·0	5·70	3·80	21·8	100	1·94	15·3	Hard, crystalline, taste good, colour pale yellow
28	B.O. 24	*Bhindi* mucilage .	81·2	6·16	4·50	9·6	178	2·03	15·8	Hard, crystalline, taste good, colour deep red
29	B.O. 24	Castor seed extract	81·0	5·70	4·64	17·9	97	1·96	13·3	Hard, crystalline, taste good, colour pale yellow
30	B.O. 24	Groundnut extract	82·6	5·13	4·14	28·5	93	1·95	13·8	Hard, crystalline, taste good, colour whitish yellow

TABLE IV

A comparison of the properties of gur *from different varieties prepared by the castor seed and groundnut extracts with* bhindi *mucilage treatment : Season 1947-48*

Replication no.	Variety	Treatments	Sucrose per cent	Glucose per cent	Moisture per cent	Pore space (cc/100g)	Colour reading (N/4 solutions)	Turbidity (N/4 solutions)	Milli eq. acid in 100g	Ash per cent	Nett Rendement	General observations
1	Co 313	*Bhindi* mucilage	79·6	4·40	5·16	23·8	120	2·00	14·3	1·84	68·8	Hard, crystalline, taste good, colour golden yellow (dull)
		Castor seed extract	78·8	4·52	4·88	24·0	75	1·73	14·8	1·86	67·8	Hard, crystalline, taste good, colour bright golden
		Groundnut extract	79·8	3·08	4·84	24·6	70	1·71	13·8	1·86	70·2	Hard, crystalline, taste good, colour bright golden
1	Co 513	*Bhindi* mucilage	80·0	5·50	4·90	24·8	135	1·96	14·8	1·92	67·8	Hard, crystalline, taste good, colour golden yellow (dull)
		Castor seed extract	84·4	5·13	4·80	25·9	65	1·84	13·3	1·90	72·6	Hard, crystalline taste good, colour bright golden
		Groundnut extract	85·0	4·52	5·00	26·3	70	1·88	12·3	1·90	73·8	Hard, crystalline, taste good, colour bright golden
1	Co 453	*Bhindi* mucilage	78·4	3·85	5·30	14·3	350	2·14	16·3	2·84	64·6	Hard, crystalline, taste good, colour dark chocolate
		Castor seed extract	85·6	3·58	4·44	17·8	140	1·85	13·8	2·88	71·9	Hard, crystalline, taste good, colour cream
		Groundnut extract	83·8	3·52	4·14	17·5	140	1·85	14·8	2·86	70·3	Hard, crystalline, taste good, colour cream
1	Co 383	*Bhindi* mucilage	76·8	7·70	5·04	15·2	275	2·18	15·8	2·70	59·7	Hard, crystalline, taste good, colour chocolate
		Castor seed extract	78·0	7·35	4·16	16·3	135	1·85	15·3	2·70	61·2	Hard, crystalline, taste good, colour light yellow
		Groundnut extract	78·8	5·50	4·10	16·3	140	1·82	15·8	2·66	64·0	Hard, crystalline, taste good, colour light yellow
2	Co 313	*Bhindi* mucilage	81·2	3·20	4·20	24·2	110	2·00	13·8	2·06	70·8	Hard, crystalline, taste good, colour, golden yellow (dull)
		Castor seed extract	81·0	3·34	4·12	27·1	60	1·83	13·8	1·98	70·7	Hard, crystalline, taste good, colour bright golden
		Groundnut extract	80·8	3·14	4·10	27·2	60	1·83	13·8	2·04	70·7	Hard, crystalline, taste good, colour bright golden

2	Co 513	*Bhindi* mucilage	50·0	5·13	5·04	20·6	125	2·00	13·8	2·12	67·5	Hard, crystalline, taste good, colour golden yellow (dull)
		Castor seed extract	79·8	4·40	4·14	21·8	70	1·78	14·3	2·10	68·1	Hard, crystalline, taste good, colour bright golden
		Groundnut extract	80·4	4·99	4·10	24·7	75	1·73	13·3	2·12	68·9	Hard, crystalline, taste good colour bright, golden
2	Co 453	*Bhindi* mucilage	80·4	4·81	4·20	11·2	300	2·33	13·8	2·52	67·4	Hard, crystalline, taste good, colour dark chocolate
		Castor seed extract	80·2	4·16	5·00	18·8	140	1·92	13·3	2·56	66·2	Hard, crystalline taste good, colour cream
		Groundnut extract	80·2	4·67	5·00	20·0	125	1·92	13·8	2·54	66·3	Hard, crystalline, taste good, colour cream
2	Co 383	*Bhindi* mucilage	78·6	4·99	4·06	13·8	215	2·06	14·3	2·44	66·0	Hard, crystalline, taste good, colour chocolate
		Castor seed extract	79·0	4·52	4·10	19·6	125	1·88	13·8	2·46	66·3	Hard, crystalline taste good, colour light yellow
		Groundnut extract	79·8	4·99	4·14	19·0	115	1·82	14·3	2·44	67·1	Hard, crystalline, taste good, colour, light yellow
3	Co 313	*Bhindi* mucilage	79·8	2·65	4·66	23·0	100	1·98	14·8	2·02	70·1	Hard, crystalline, taste good colour golden yellow (dull)
		Castor seed extract	80·2	2·56	4·80	25·8	55	1·72	15·3	1·98	70·7	Hard crystalline, taste good, colour bright golden
		Groundnut extract	79·6	2·65	4·94	27·3	60	1·67	15·3	2·04	69·8	Hard, crystalline, taste good colour bright golden
3	Co 513	*Bhindi* mucilage	80·8	2·44	5·00	19·7	110	1·95	14·3	2·14	70·9	Hard, crystalline, taste good, colour golden yellow (dull)
		Castor seed extract	80·6	2·56	4·06	22·9	60	1·67	13·3	2·12	70·6	Hard, crystalline taste good, colour bright golden
		Groundnut extract	81·0	2·48	4·10	23·0	60	1·73	12·3	2·14	71·0	Hard, crystalline, taste good, colour bright golden
3	Co 453	*Bhindi* mucilage	74·6	3·01	5·06	10·7	315	2·12	15·8	3·06	60·9	Hard, crystalline, taste good, colour dark chocolate
		Castor seed extract	74·4	2·99	5·10	17·0	150	2·00	14·3	3·02	60·8	Hard, crystalline, taste good, colour cream
		Groundnut extract	75·0	3·08	4·24	17·3	120	1·83	13·8	3·10	61·1	Hard, crystalline, taste good, colour cream

TABLE IV

A comparison of the properties of gur *from different varieties prepared by the castor seed and groundnut extracts with* bhindi *mucilage treatment : Season 1947-48*—contd.

Replication No.	Variety	Treatments	Sucrose per cent	Glucose per cent	Moisture per cent	Pore space (cc/100g)	Colour reading (N/4 solutions)	Turbidity (N/4 solutions)	Milli eq. acid in 100 g	Ash per cent	Nett Rendement	General observations
3	Co 383	*Bhindi* mucilage	74·2	2·83	5·00	15·3	250	2·10	15·3	2·42	62·9	Hard, crystalline, taste good, colour chocolate
		Castor seed extract	74·8	2·85	5·02	19·0	160	1·87	15·3	2·46	63·3	Hard, crystalline, taste good colour light yellow
		Groundnut extract	74·2	2·70	4·98	20·0	153	1·87	14·8	2·38	63·2	Hard, crystalline, taste good colour light yellow
4	Co 313	*Bhindi* mucilage	80·4	2·44	4·16	18·7	115	2·04	15·8	1·94	71·2	Hard, crystalline, taste good, colour golden yellow (dull)
		Castor seed extract	80·6	2·29	4·06	20·5	60	1·67	14·3	1·88	71·7	Hard, crystalline, taste good, colour bright golden
		Groundnut extract	80·2	2·33	4·10	20·1	60	1·75	14·8	1·98	70·9	Hard, crystalline, taste good, colour bright golden
4	Co 513	*Bhindi* mucilage	79·6	2·44	5·00	27·2	110	1·95	16·8	2·24	69·3	Hard, crystalline, taste good, colour golden yellow (dull)
		Castor seed extract	79·6	2·48	5·08	28·0	65	1·84	14·3	2·28	69·1	Hard, crystalline, taste good, colour bright golden
		Groundnut extract	79·6	2·35	4·08	27·2	60	1·75	14·3	2·24	69·4	Hard, crystalline, taste good, colour bright golden
4	Co 453	*Bhindi* mucilage	79·0	3·27	5·00	15·8	300	2·18	17·3	2·74	66·1	Hard, crystalline, taste good, colour dark chocolate
		Castor seed extract	79·4	3·20	5·00	22·0	160	1·90	16·3	2·80	66·4	Hard crystalline, taste good, colour cream
		Groundnut extract	79·6	3·08	5·10	22·6	135	1·88	16·3	2·74	66·9	Hard, crystalline, taste good, colour cream
	Co 383	*Bhindi* mucilage	73·0	3·67	5·02	18·0	270	2·15	15·8	2·38	61·0	Hard, crystalline, taste good, colour chocolate
		Castor seed extract	73·2	3·85	4·01	25·0	145	1·89	15·8	2·26	61·4	Hard, crystalline, taste good, colour light yellow
		Groundnut extract	73·0	3·42	4·06	22·1	125	1·83	14·8	2·30	61·3	Hard, crystalline, taste good, colour light yellow

TABLE V

A comparison of the properties of gur *prepared from immature canes by the castor seed and groundnut extracts with* bhindi *mucilage treatment: Season 1947-48*

Replication No.	Variety	Treatments	Sucrose per cent	Glucose per cent	Moisture per cent	Pore space (cc/100g)	Colour reading (N/4 solutions)	Turbidity (N/4 solutions)	Milli eq. acid in 100g.	Ash per cent	Nett Rendement	General observations
1	Co 313	*Bhindi* mucilage . .	68·6	6·16	7·50	15·0	200	2·18	22 0	3·24	51·1	Hard, not quite crystalline, taste good, colour dark red
		Castor seed extract .	69·0	5·70	5 70	16·9	120	1·87	17·3	3·26	51·9	Hard, crystalline, taste good, colour brownish yellow
		Groundnut extract .	69·2	5·70	5 00	17 7	110	1·82	17·3	3·24	52·1	Hard, crystalline, taste good. colour brownish yellow
2	Co 313	*Bhindi* mucilage . .	68 8	5·70	7·46	13 2	225	2·13	22·5	3 26	51·7	Hard, not quite crystalline, taste good colour dark red
		Castor seed extract .	69·6	5·50	4·94	17·0	110	1·82	16·3	3·26	52·7	Hard, crystalline, taste good, colour brownish yellow
		Groundnut extract .	69·4	5 31	5·00	16 3	105	1·81	16·8	3·28	52·6	Hard, crystalline, taste good, colour brownish yellow
3	Co 313	*Bhindi* mucilage . .	69·0	5·70	6 64	12 5	220	2 16	22·0	3 26	51·9	Hard, not quite crystalline. taste good, colour dark red
		Castor seed extract .	69 6	5·31	5 72	19 8	100	1·85	15·8	3·24	53·0	Hard, crystalline, taste good, colour brownish yellow
		Groundnut extract .	69 8	5·31	5 74	20 0	105	1 81	16·8	3·24	53·2	Hard. crystalline, taste good. colour brownish yellow
4	Co 313	*Bhindi* mucilage .	71·0	5·31	6 60	13 7	215	2 09	23 0	3 22	54·4	Hard, not quite crystalline. taste good, colour dark red
		Castor seed extract .	69 8	4·97	4 90	20 2	100	1·98	16 3	3 20	53·6	Hard, crystalline. taste good, colour brownish yellow
		Groundnut extract .	69 6	5 13	5 74	20 9	100	1 90	17·3	3·24	53 1	Hard, crystalline, taste good, colour, brownish yellow
5	Co 313	*Bhindi* mucilage . .	70·4	5·50	6 60	13·0	200	2 25	21 0	3·14	53·9	Hard, not quite crystalline. taste good. colour dark red
		Castor seed extract .	70 0	5·13	5·00	19·5	105	1 90	15·3	3·14	53 9	Hard. crystalline, taste good. colour brownish yellow
		Groundnut extract .	70 0	5 13	5·00	20·4	105	1·90	15·8	3·12	53·9	Hard, crystalline, taste good, colour brownish yellow

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TABLE VI

A comparison of the properties of gur *from water logged canes prepared by the castor seed and groundnut extract with* bhindi *mucilage treatment : Season 1947-48*

Replication No.	Variety	Treatments	Sucrose per cent	Glucose per cent	Moisture per cent	Pore space (cc/100g)	Colour reading	Turbidity	Milli eq. acid in 100g.	Ash per cent	Nett Rendement	General observations
							N/4 solutions					
1	Mixed (Same juice for all treatments)	*Bhindi* mucilage . .	72·4	5·70	6·00	10·5	330	1·98	24·5	3·04	56·1	Not quite hard on crystalline taste indifferent. colour very dark chocolate
		Castor seed extract .	72·6	5·70	5·84	14·3	165	1·94	21·0	3·02	56·3	Hard, crystalline, taste good. colour yellowish brown
		Groundnut extract .	72·4	5·50	5·90	13·1	158	1·96	20·5	3·08	56·1	Hard, crystalline, taste good. colour yellowish brown
	do	*Bhindi* mucilage . .	74·0	6·16	5·02	9·8	325	1·97	22·0	2·90	57·7	Not quite hard or crystalline, taste indifferent. colour very dark chocolate
		Castor seed extract	74·6	6·42	4·94	15·0	160	1·87	20·0	2·92	58·0	Hard crystalline. taste good. colour yellowish brown
		Groundnut extract	74·4	6·16	5·88	14·8	160	1·87	19·5	2·90	58·1	Hard crystalline. taste good, colour yellowish brown
8	do	*Bhindi* mucilage .	75·0	6·16	5·80	12·7	300	2·03	23·0	3·28	57.4	Not quite hard or crystalline taste, indifferent colour very dark chocolate
		Castor seed extract .	75·0	6·42	5·00	14·9	130	1·92	19·5	3·30	57·0	Hard, crystalline. taste good, colour yellowish brown
		Groundnut extract .	74·8	5·92	5·92	15·8	118	1·90	19·5	3·40	57·0	Hard, crystalline, taste good, colour yellowish brown

TABLE VII

A comparison of the properties of gur *prepared by the castor seed, groundnut,* deola *and* falsa *extract treatments : Season 1947-48*

Replication No.	Variety	Treatments	Sucrose per cent	Glucose per cent	Moisture per cent	Pore space (cc/100g)	Colour reading	Turbidity	Millieq. acid in 100g	Ash per cent	Nett Rendement	General observations
							N/4 solutions					
1	Co 513	*Deola* mucilage	80·2	3·58	5·00	25·0	95	2·00	13·8	2·06	68·0	Hard, crystalline, taste good, colour dull yellow
		Falsa extract	78·4	4·40	4·94	24·0	130	2·00	13·8	2·02	66·4	Hard, crystalline, taste good, colour yellowish brown
		Castor seed extract	80·2	3·42	4·14	23·1	62	1·77	14·3	2·06	66·9	Hard, crystalline, taste good, colour bright golden
2	Co 513	*Deola* mucilage	79·6	4·81	4·10	23·7	100	2·15	12·8	2·12	68·1	Hard, crystalline, taste good, colour dull yellow
		Falsa extract	78·6	5·13	4·96	24·5	145	1·89	14·3	2·04	66·5	Hard, crystalline, taste good, colour yellowish brown
		Castor seed extract	79·4	3·99	4·18	25·8	65	1·76	12·3	2·10	67·9	Hard, crystalline, taste good, colour bright golden
3	Co 513	*Deola* mucilage	80·8	4·52	4·88	22·0	100	2·00	14·3	1·94	67·5	Hard, crystalline, taste good, colour dull yellow
		Falsa extract	80·0	4·40	4·90	21·6	150	2·00	13·8	1·98	68·7	Hard, crystalline, taste good, colour yellowish brown
		Castor seed extract	80·4	4·27	4·06	23·2	60	1·92	13·3	1·92	69·4	Hard, crystalline, taste good, colour bright golden
1(*a*)	Co 513	*Deola* mucilage	80·0	4·05	4·10	24·3	100	2·00	14·8	2·04	68·8	Hard, crystalline, taste good, colour dull, yellow
		Falsa extract	80·0	4·16	4·90	21·3	130	2·00	14·3	2·04	67·9	Hard, crystalline, taste good, colour yellowish brown
		Groundnut extract	80·8	4·05	4·20	24·5	60	1·67	13·3	2·06	69·4	Hard, crystalline, taste good, colour bright golden
2(*a*)	Co 513	*Deola* mucilage	79·0	4·05	5·02	20·1	90	2·02	14·8	1·98	67·1	Hard, crystalline, taste good, colour dull yellow
		Falsa extract	79·0	4·05	5·00	19·1	125	2·08	14·8	2·02	66·9	Hard, crystalline, taste good, colour yellowish brown
		Groundnut extract	79·8	4·05	5·00	22·0	58	1·89	14·3	2·02	67·7	Hard, crystalline, taste good, colour bright golden
3(3)	Co 513	*Deola* mucilage	78·2	4·16	4·10	23·7	97	2·01	14·3	1·96	67·2	Hard, crystalline, taste good, colour dull yellow
		Falsa extract	77·4	4·05	4·16	21·0	130	2·11	14·3	1·98	66·4	Hard, crystalline, taste good, colour yellowish brown
		Groundnut extract	78·2	3·85	4·10	25·9	65	1·84	14·3	1·98	67·4	Hard, crystalline, taste good, colour bright golden

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Table VIII

A statistical comparison of the properties of gur *prepared by the* bhindi *mucilage, castor seed extract and groundnut extract treatments : Season 1947-48*

Treatments / Characters	*Bhindi* mucilage (B)	Castorseed extract (C)	Groundnut extract (G)	Conclusions
Sucrose	78·53	79·35	79·43	CD at 5 per cent = 1.50; at 5 per cent: $\overline{GCB}$; non-significant
Glucose	3·90	3·74	3·53	CD at 5 per cent = 0.54; at 5 per cent: $\overline{BCG}$; non-significant
Moisture	4·80	4·55	4·44	CD at 5 per cent = 0·30; at 5 per cent: $B\overline{CG}$; non-significant
Pore space	18·39	21·84	22·00	CD at 5 per cent=1·87; CD at 1 per cent = 2.52; at 5 per cent: $G\overline{CB}$; at 1 per cent: $\overline{GCB}$; highly significant
Colour (N/4 solution)	200	104	98	CD at 5 per cent = 9.4; CD at 1 per cent = 12.6; at 5 per cent. $B\overline{CG}$; at 1 per cent $\overline{BCG}$: highly significant
Turbidity (N/4 solution)	2·07	1·83	1·81	CD at 5 per cent=0.04; CD at 1 per cent = 0.06; at 5 per cent: $B\overline{CG}$, at 1 per cent: $\overline{BCG}$; highly significant
Acidity	15·18	14·46	14·27	CD at 5 per cent = 0.52; at 5 per cent: $B\overline{CG}$; non-significant
Ash	2·34	2·33	2·33	CD at 5 per cent = 0.11; at 5 per cent: $B\overline{(GC)}$; non-significant
Nett Rendement	66·6	67·4	67·8	CD at 5 per cent: 1.81; at 5 per cent: $\overline{GCB}$; non-significant

TABLE IX

A statistical comparison of the properties of gur *prepared from immature canes by the* bhindi *mucilage, castor seed extract and groundnut extract treatments: Season 1947-48*

Treatments / Characters	*Bhindi* mucilage (B)	Castor seed extract (C)	Groundnut extract (G)	Conclusions
Sucrose	69·6	69·6	69·6	CD at 5 per cent = 0.75; at 5 per cent: ($\overline{BCG}$); non-significant
Glucose	5·67	5·32	5·32	CD at 5 per cent=0.11; CD at 1 per cent = 0.16; at 5 per cent: B$\overline{CG}$, at 1 per cent: B$\overline{CG}$; highly significant
Moisture	6·96	5·25	5·30	CD at 5 per cent=0.67; CD at 1 per cent = 0.97; at 5 per cent: B$\overline{GC}$ at 1 per cent: B$\overline{GC}$; highly significant
Pore space	13·5	18·7	19·1	CD at 5 per cent=2.87; CD at 1 per cent = 4.17 at 5 per cent: $\overline{GC}$B; at 1 per cent: $\overline{GC}$B; highly significant
Colour (N/4 solution)	212	107	105	CD at 5 per cent=18.88; CD at 1 per cent: 27.47; at 5 per cent: B$\overline{CG}$ at 1 per cent. B$\overline{CG}$; highly significant
Turbidity (N/4 solution)	2·16	1·88	1·85	CD at 5 per cent =0.06; CD at 1 per cent = 0.11; at 5 per cent: B$\overline{CG}$; at 1 per cent: B$\overline{CG}$, highly significant
Acidity	22·1	16·2	16·8	CD at 5 per cent=0.57; CD at 1 per cent = 0.83; at 5 per cent: B$\overline{GC}$; at 1 per cent: B$\overline{GC}$; highly significant
Ash	3·22	3·22	3·22	CD at 5 per cent = 0.03; at 5 per cent: ($\overline{BCG}$); non-significant
Nett Rendements	52·6	53·0	53·0	CD at 5 per cent: 0.81; at 5 per cent: $\overline{CGB}$; non- significant

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Table X

A statistical comparison of the properties of gur *prepared from water logged canes by the* bhindi *mucilage, castor seed extract and groundnut extract treatments :*
Season 1947-48

Treatments / Characters	*Bhindi* mucilage (B)	Castor seed extract (C)	Groundnut extract (G)	Conclusions
Sucrose	73·8	74·1	73·9	CD at 5 per cent = 0.39 ; at 5 per cent : $\overline{CGB}$; non-significant
Glucose	6·01	6·18	5·86	CD at 5 per cent = 0.24 ; at 5 per cent : $\overline{CB}G$; significant
Moisture	5·61	5·26	5·90	CD at 5 per cent=0·75 ; at 5 per cent : $\overline{GBC}$; non-significant
Pore space	11·0	14·7	14·6	CD at 5 per cent = 2.065 ; at 5 per cent : CGB ; significant
Colour (N/4 solution)	318	152	145	CD at 5 per cent = 10.13 ; at 1 per cent=16.80 ; at 5 per cent : BCG ; at 1 per cent : B$\overline{CG}$; highly significant
Turbidity (N/4 solution)	1·99	1·91	1·91	CD at 5 per cent = 0.07 ; at 5 per cent : B($\overline{CG}$) ; significant
Acidity	23·2	20·2	19·8	CD at 5 per cent=1.11 ; CD at 1 per cent = 1.84 ; at 5 per cent : B$\overline{CG}$; at 1 per cent : $\overline{BCG}$; highly significant
Ash	3·07	3·08	3·13	CD at 5 per cent = 0.09 ; at 5 per cent : GCB ; non-significant
Nett Rendement	57·1	57·1	57·1	CD at 5 per cent = 0.50 ; at 5 per cent : ($\overline{BCG}$) ; non-significant

Table XI

A statistical comparison of the properties of gur *prepared by the* deola, falsa *bark and castor seed extract treatments : Season 1947-48*

Treatments / Characters	*Deola* mucilage (D)	*Falsa* bark mucilage (F)	Castor seed extract (C)	Conclusions
Sucrose	81·2	79·0	80·0	CD at 5 per cent = 0.83 ; at 5 per cent : $\overline{\text{DCF}}$; significant
Glucose	4·30	4·64	3·89	CD at 5 per cent = 0.75 ; at 5 per cent : $\overline{\text{FDC}}$; non-significant
Moisture	4·66	4·93	4·13	CD at 5 per cent = 0·69 ; at 5 per cent : $\overline{\text{FDC}}$; non-significant
Pore space	23·6	23·7	24·7	CD at 5 per cent = 1.29 ; at 5 per cent : $\overline{\text{CFD}}$; non-significant
Colour (N/4 solution)	98	142	62	CD at 5 per cent = 12.83 ; at 1 per cent=21.27 ; at 5 per cent : FDC ; at 1 per cent : FDC ; highly significant
Turbidity (N/1 solution)	2·05	1·96	1·82	CD at 5 per cent = 0.21 ; at 5 per cent : $\overline{\text{DF}}\underline{\text{C}}$; non-significant
Acidity	13·6	14·0	13·3	CD at 5 per cent = 1.64 ; at 5 per cent : $\overline{\text{FDC}}$; non-significant
Ash	2·04	2·01	2·03	CD at 5 per cent = 0.082 ; at 5 per cent : $\overline{\text{DCF}}$; non-significant
Nett Rendement	67·9	67·2	68·1	CD at 5 per cent = 2.11 ; at 5 per cent : $\overline{\text{CDF}}$; non-significant

TABLE XII

A statistical comparison of the properties of gur *prepared by the* deola, falsa *bark and groundnut extract treatments : Season 1947-48*

Treatments / Characters	*Deola* mucilage (D)	*Falsa* bark mucilage (F)	Groundnut extract (G)	Conclusions
Sucrose	79·1	78·8	79·6	CD at 5 per cent = 0.58 ; at 5 per cent : GDF ; significant
Glucose	4·09	4·09	3·98	CD at 5 per cent = 0.22 ; at 5 per cent : $\overline{(DF)G}$; non-significant
Moisture	4·41	4·69	4·43	CD at 5 per cent = 0.56 ; at 5 per cent : $\overline{FGD}$; non-significant
Pore space	22·7	20·5	24·1	CD at 5 per cent=1.72 ; at 5 per cent : GDF ; significant
Colour (N/4 solution)	96	128	61	CD at 5 per cent=5.32 ; CD at 1 per cent=9·82 ; at 5 per cent : FDG ; at 1 per cent : FDG ; highly significant
Turbidity (N/4 solution)	2·01	2·06	1·80	CD at 5 per cent = 0.125 ; at 1 per cent = 0.21 ; at 5 per cent : FDG ; at 1 per cent : $\overline{FDG}$; highly significant
Acidity	14·6	14·5	14·0	CD at 5 per cent = 0.89 ; at 5 per cent : $\overline{DFG}$; non-significant
Ash	1·99	2·02	2·02	CD at 5 per cent = 0.02 ; at 5 per cent : ($\overline{FG}$)D ; significant
Nett Rendement	67·7	67·1	68·2	CD at 5 per cent =0.55 ; at 5 per cent : GDF ; significant

TABLE XIII

A comparison of chemical characteristics at different extracts

Extract	Crude* proteins	True† proteins	True proteins per cent crude proteins	Ash	Soluble SiO_2	P_2O_5	Al_2O_3 + Fe_2O_3	CaO	MgO
Bhindi	79	13	16·4	92	16	2	4	3	Traces
Deola	316	61	19·3	120	12	3	8	2	Traces
Falsa	97	22	22.5	134	8	1	3	4	Traces
Castor seed	586	569	97·1	122	18	8	7	Traces	Traces
Groundnut	1164	892	76·6	118	22	9	39	Traces	Traces

* Determined by the usual Kjeldahl method
† Precipitation with Stutzer's (copper hydroxide) reagent and then determined by Kjeldahl method

TABLE XIV

Showing yields of gur *on juice*

Month	*Gur* per cent juice (average)		
	Castor seed extract clarification	*Bhindi* mucilage clarification	Groundnut extract clarification
November	15·8	15·3	15·3
December	16·7	17·0	16·6
January	17·4	17·3	16·7
February	17·7	17·2	16·9
March	18·0	17·6	19·1
Seasonal average	17·1	16·9	16·9

INVESTIGATIONS ON THE ALKALINITY AND SALTISHNESS IN *GUR* MADE FROM COIMBATORE SUGARCANE VARIETIES*

By P. G. Krishna, B. Sc., Ph. D. (Cornell), Agricultural Chemist to H. E. H. the Nizam's Government, Hyderabad-Deccan

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PRIOR to 1930, sugarcane cultivation in Hyderabad-Deccan was restricted to isolated areas under wells and tanks. It was mostly for the manufacture of *gur* (jaggery) and partly for chewing, both to meet local demand only. The local variety of sugarcane called '*desi*' was commonly grown. It was crimson-striped or white, medium thick and soft. The cultivation used to be in flat beds. As the plants were lodging they had to be supported. Expenses in this direction were enormous. Water-logging wherever it occurred adversely affected the crop. Damage due to pigs was considerable. In view of these difficulties, there was a search by the Department of Agriculture for a non-lodging, hardy sugarcane which was at the same time a high yielder. Coimbatore 213 was found to be quite satisfactory. So, around 1930, this variety was introduced all over the State along with the new method of trench cultivation. Soon it became popular and area under sugarcane began to spread rapidly. However, shortly afterwards, complaints began to be received from project areas of Nizamasagar, Vaira and Paler that *gur* made from this new variety (Co. 213) was saltish.

It was, therefore, decided that this problem should be fully investigated

Literature

The mineral composition of sugarcane juice with particular reference to the soils and irrigation waters has received the attention of several workers. Varahalu [1935-36] observed that saline soils, dry conditions and brackish water produce sugercane juice with a large amount of non-sugar organic matter. Lander and Ramji Narain [1939] noticed that soils with low exchangeable calcium produce caned the of abnormally high mineral content. Mc Kaig and Fort [1938] have attribute juice differences in quality of juice to the types of soils used by them. Swadi [1919] stated that grey soils, and brackish water containing too much of magnesium salts particularly chlorides, are responsible for the bad keeping quality and hardness of *gur*. He noticed that the salinity was distinctly marked even to the taste. It was just a general reference.

Sanyal [1928], Varhalu [1936], and Bhushanam [1945] have indicated that the application of inorganic fertilizers, especially nitrogenous, produces *gur* of low keeping quality. It is not so with organic fertilizers. Krishnamurthy Rao [1919] showed that the chlorine absorbed by canes from soil and irrigation waters was responsible for production of jaggery of bad quality. Norris, Vishwanath and Govinda Nayar [1922] attributed the bad keeping quality of jaggery to its calcium and magnesium chloride contents and stated that it is not chlorine or sodium chloride that impair the keeping quality of juice but highly deliquescent compounds of chlorine.

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Thus, almost all the earlier workers have particularly dealt with factors governing the keeping quality of *gur* but not its taste. Swadi [1919] seems to be the only one who had noticed saltishness in *gur* but his was merely a passing reference.

Object of investigation

Keeping in view the important findings of these workers regarding the effect of soils, irrigation waters, and fertilizers, the author has attempted in the present investigation to find out the cause of saltishness in *gur*, whether it is dependent on total salt content or any particular item and what the correlation is. So far, nobody seems to have thought that ratooning introduces some changes as well. The author has attempted to deal with that aspect also. Thirdly, keeping in view the general observation of Krishnamurthy Rao [1919] that thick canes absorb less chlorine than thin ones, the author has made an elaborate and systematic study of the differential absorption of sugarcane varieties.

Experimental work

Gur samples made from Co. 213 and from Local cane were obtained from many parts of the State for analysis. *Gur* samples from several Coimbatore sugarcane varieties grown on different experiment stations were also obtained. Their colour, hardness and taste were noted and then the percentages of moisture, sucrose, glucose, ash, alkalinity, chlorine and sulphate determined by analysis. Some of the soils and irrigation waters used for growing sugarcanes were also analyzed for the water-soluble salts. In all about 400 samples were analyzed for various items during the seven years of investigation.

Alkalinity in gur

Alkalinity is expressed in cubic centimeters of normal acid required to neutralize the ash obtained from 100 grammes of *gur*. Table I indicates that in the case of local sugarcanes alkalinity varied from 3·9 to 8·8. Only in one instance it was 17·5 and it is quite possible that this high alkalinity is due to the presence of alkaline salts in wood ash used as a clarifying agent in the manufacture of *gur*. None of the *gur* samples made from local cane was saltish. All these samples were obtained from old sugarcane areas in different parts of the State.

Of the *gur* samples obtained from Himayatsagar farm those of Co. 213, 223 and 290 were saltish while varieties such as Hebbal Mysore, P. O. J., E. K. and Fiji B were not. The alkalinity in the ash of *gur* of Co. 213, 223 and 290 was also quite high varying considerably from 3 to 12. That such varietal differences may be expected was indicated by Krishnamurthy Rao [1919] for thick and thin canes.

Of the samples obtained from Rudrur farm, Nizamabad district, only 2 out of 17 were saltish and the total alkalinity was 3 to 9 which is somewhat lower than the Himayatsagar samples. Alkalinity was about the same in *gur* made from Co. 213 cultivated in both the clay loams (*regur*) and red sandy loams (*chalka*). It may be noted that on the Himayatsagar and Rudrur farm soils sugarcane crops were not previously cultivated.

Amongst the Parbhani samples, only one (*i.e.*, Co. 290) was saltish. Alkalinity in them was as low as 3 to 6 which is considerably less than in the samples from the other two farms.

The sugarcane soils at Himayatsagar vary from light to heavy clay loams derived from granitoid gneissic complex while those of Rudrur vary from red sandy loams to clay loams being of a mixed origin in as much as they are derived from both basalt and granitoid gneissis as the farm is located at the base of a basalt hill which is an intrusion in the granitoid gneissic area. The sugarcane soils of Parbhani are clay loams derived from basalt (trap).

From the foregoing evidence, it seems that the type of soil governs to some extent the composition of juice (as reflected in *gur*) obtained from sugarcanes growing therein. This is in agreement with the observation of Mc Kaig and Fort [1938].

From Table I, it seems that *gur* made from Coimbatore and other sugarcane varieties cultivated in different areas has a varying alkaline content. This is further borne out by the data for three successive years in Table II in which canes cultivated at Himayatsagar farm show a higher alkalinity in *gur* as compared to the same canes grown at Rudrur farm. Therefore, any variation in alkalinity of *gur* may not be a varietal characteristic. The cause may be due to factors such as climate, soil, irrigation water. and manurial treatments. Bhushanam [1945], Sanyal [1928], Varahalu [1935-36], and Willcox [1946] have shown that the manurial treatments have a definite effect on the composition of juice. But here, the manurial treatments at both the farms were about the same and consisted of green manuring and an application of 100 to 150 pounds of nitrogen per acre in the form of castor and groundnut cakes. As such, the variation in alkalinity may be due to the other three factors.

An analysis of the samples of sugarcane soils and irrigation waters at both the Himayatsagar and Rudrur farms (Table III) indicates that the water soluble salt content of the soils at both the farms is about the same at the time of sampling, while that for irrigation waters is considerably higher at Himayatsagar. If these were considered along with climatic factors, especially the annual rainfall, the cause for lower alkali salt content of *gur* samples from Rudrur farm becomes evident. The annual rainfall on Himayatsagar farm varies from 20 to 25 inches while that on Rudrur farm from 35 to 45 inches. Although the total water soluble salt content of soils on both farms at the time of sampling (*i. e.*, in summer months) is about the same, this is likely to vary a great deal during the monsoon months. At Rudrur, with almost twice the amount of rainfall, it is bound to be considerably lower as we know that the chlorides are easily translocated. and the other salts to a lesser extent, by washing or leaching.

Another important difference is in the number of irrigations. The sugarcane crop at Himayatsagar has to be irrigated much more than at Rudrur ; and as the quality of the waters differs, the effect of frequent irrigations as at Himayatsagar would be to add larger amounts of alkali salts to the soil, which are absorbed by the sugarcane crop, and which in turn increase the alkalinity in *gur*. Hence, it may be

deduced, that the composition of the soil and irrigation waters used for growing sugarcanes is greatly reflected in the alkalinity of *gur* obtained therefrom.

A similar but somewhat modified relationship has been indicated by some other workers [Holmes, 1938 ; Lander and Chopra 1942 ; Lander and Ramji Narain, 1936, 1939 ; Norris, Viswanath and Govindanayar, 1922, 1924 ; Sanyal, 1928]. It was in connection with the keeping quality and hardness of *gur*, which are stated to be dependent on the salt content of sugarcane juice, that is controlled and modified by the mineral composition of the soil and irrigation waters.

Effect of ratooning on the alkalinity in gur

In Table IV are given the data for alkalinity in *gur* made from Coimbatore sugarcane varieties 213, 223, 281 and 290, both from plant (new crop) and ratoon canes for three successive years. It is seen, that *gur* made from ratoon cane has invariably less alkalinity than that from plant cane of the same variety. This indicates that on continued cane cultivation there is a decrease in the alkaline salt content of *gur*, probably because of the reduction in salt content of the soils as some of the salts are absorbed by the first cane crop, thus leaving less salts for absorption by the succeeding cane crop.

Another noteworthy feature is, that in *gur* made from ratoon canes, a greater number is sweet as compared to *gur* from plant canes of the same variety, excepting in the year 1935 when the rainfall received was one of the lowest on record being only 17·74 inches during the sugarcane season when there was not much difference in this respect.

Relation between total alkalinity in ash of gur *and taste*

From a perusal of Tables I, II and V it is seen that there is no relation at all between total alkalinity in ash of *gur* and their taste, as some of the *gur* samples with very low alkalinity are saltish, while some with quite high alkalinity are sweet.

Selective absorption of sugarcane varieties

In Table V are recorded the total alkalinity in ash of *gur* and taste of *gur* for 20 leading sugarcane varieties which were under trial at Himayatsagar farm for three years. Table VI gives further record of 18 of these varieties for another four years. As pointed above, it is seen that there is no relation between total alkalinity and saltishness. It might however be noted that of these several varieties, some responded quite consistently during all these years, either being always saltish or always sweet. *Gur* of variety Co. 419 was always sweet and of Co. 434, 429 and 509 mostly sweet. Co. 290 and 513 always gave saltish *gur*. In some of the varieties like Co. 408, 421, 423, 520 and 524 the *gur* samples were sweet for about half the replications and saltish for the rest. Co. 301 which has come to lead in the yield of sugarcane during the last four years is similar to Co. 290 in saltishness. Co. 426,

331, 313 and 532 mostly yielded saltish *gur*. Co. 244 seems somewhat better than Co. 301 and 290. The rest of the varieties sometimes yielded sweet *gur* and sometimes saltish and were not consistent. The manifestation of these differences has occurred inspite of the varieties having been planted in a randomized manner. It is likely, therefore, that these varieties are all selective in their absorbing capacity for salts in the soil and irrigation waters, some avoiding some particular salts and others preferring them. As will be seen from the discussion to follow, chlorides which are responsible for saltishness are probably not absorbed to such a great extent by sugarcane varieties always yielding sweet *gur* as those always yielding saltish *gur*.

These findings are generally at variance with those of Krishnamurthy Rao [1919] who concluded that thick juicy canes do not absorb as much chlorine as thin hardy varieties. Norris, Viswanath and Nayar [1924] do not refer to saltishness in *gur* at all, but state that the keeping quality is impaired by deliquescent compounds of chlorine.

Saltishness in gur

Gur samples made from the 18 varieties under trial at the Himayatsagar Farm with four replications of each variety were analyzed to determine as to what constituent in the ash of *gur*, is responsible for saltishness. Results of these analyses are given in Table VI. It will be seen from the results that the constituents of the ash of *gur* vary for the same variety in the different replications, and that *gur* of the same variety in some plots is saltish while in others it is sweet. This is probably due to the uneven distribution of salts in the different plots.

Total alkalinity and sulphates do not seem to exert any specific effect on the taste of *gur*. Samples containing over 0·50 per cent of chloride content are generally saltish and almost all samples containing less than 0·50 per cent chlorine (0·82 per cent NaCl) are sweet even though the total alkalinity and sulphates are quite high. Taking the average of four years, of the 72 samples only 42 are saltish and 30 sweet. Amongst them, there were only four samples with less than 0·50 per cent chlorine that were saltish and only four samples with more than 0·50 per cent chloride that were sweet. Thus the correlation between the chlorine content of *gur* and taste seems to be quite convincing. Generally speaking, if *gur* samples contain over 0·50 per cent of chlorine they would be saltish, while those containing less would be sweet.

The sulphate content of *gur* varied from 0·17 to 1·05 per cent. These are two extreme samples out of a total of 288 during the four years. In 1939-40, a *gur* sample made from Co. 434, contained 1·05 per cent sulphate and only 0·43 per cent chlorine. It was not saltish, although the taste was unpleasant.

Samples high in total alkalinity usually have a biting taste but not saltish if the chlorine content is less than 0·5 per cent.

Other observations

Vaticol, a patented vegetable carbon, was used in the manufacture of *gur* in 1939-40 to get a light-coloured product in the first and second replications of Co. 419, 421, 423, 520, 523, 524, 530 and 532 and in the first and third replications of the remaining ten varieties. It did not have any effect, either on alkalinity in the ash of *gur* or on taste of *gur*.

Incidentally, there does not seem to be any definite relation between saltishness and texture of *gur* samples.

Recommendation

It is now evident why complaints of saltishness in *gur* of Coimbatore sugarcane varieties are received only from new sugarcane areas. In the old areas, the salts present in the soil, especially chlorides which are responsible for saltishness, were either removed by the previous sugarcane crops or leached out; hence sweet *gur* results. In the new areas on the other hand, the sugarcane crop itself absorbs the salts from the soil; and if chlorides are present, saltish *gur* is produced. This does not present a problem to cane growers in the factory areas, as all the cane is sold to the factory. In the non-factory areas, however, where sugarcane is being newly introduced, this fact must be taken into account. As a safeguard, therefore, one may grow a variety of sugarcane like Co. 419 which always yields sweet *gur*, or grow at least two crops of paddy prior to sugarcane cultivation in order to leach out the salts present in the soil and to minimise the chances of producing saltish *gur* which would naturally command a lower price in the market.

Some of the varieties like Co. 290 and 301 which seem to absorb large amounts of salts in the soil, may be cultivated in saline soils along with systematic leaching. Co. 290 is found to be a very hardy cane, able to thrive in waterlogged conditions also. As such, it can be recommended for waterlogged soils as well as reclamation of saline soils.

Summary

Coimbatore sugarcane varieties when cultivated in new areas, yield *gur*, high in alkalinity in ash directly depending upon the water soluble salts in the soils and irrigation waters which are absorbed by the plants.

The alkalinity in ash is lower in *gur* made from ratoon sugarcanes than in *gur* from plant (new crop) canes. Also a great number of *gur* samples from ratoon canes is sweet or less saltish than from new crop. This indicates that on continued cane cultivation, the *gur* produced will tend to be less alkaline and less saltish to taste. In other words, it tends to become sweet.

Sweet *gur* was always yielded by Coimbatore sugarcane variety 419, and almost always by 434. On the other hand, Co. 290, 301 and 214 always gave saltish *gur*. This may be a varietal characteristic indicating selective absorption of the salts present in the soil.

There was no correlation between the taste of *gur* and total alkalinity in its ash. Some *gur* samples with high alkalinity had a sweet taste while others with very low alkalinity had saltish taste.

Saltishness in *gur* is due to the presence of chlorides in it. If the chlorine content is more than 0·50 per cent the *gur* tastes saltish. The sulphate content has no such effect.

For new irrigated areas, it is suggested that a variety of sugarcane like Co. 419 which always yields sweet *gur* may be grown. In the alternative, prior to the introduction of Coimbatore sugarcane varieties, ryots may be advised to cultivate paddy for at least two seasons before planting cane, so that the chances of obtaining saltish *gur* become minimized.

For reclaiming saline areas Co. 290, a very hardy variety, may be recommended along with systematic leaching, as this variety not only absorbs large amounts of salts but also withstands water-logging.

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TABLE I

Analysis of 'Gur' samples from different localities of the State and Govt. farms, 1934

Serial number	Variety	Locality	Description	Moisture per cent	Sucrose per cent	Reducing sugars per cent	Ash per cent	Alkalinity in ash per 100 gms. sample	Remarks (clarifiers, manures, etc.)
1	Co. 213	Himayat sagar farm	Reddish brown, soft, saltish	5·18	86·67	5·26	3·16	13·50 cc. N. acid	Sajjikhar, and *bhendi* juice as clarifier
2	Co. 213	do.	do	6·06	84·84	2·86	3·39	11·9 ,,	do.
3	Co. 213	do.	Reddish brown, hard	4·28	83·44	5·71	3·10	8·1 ,,	do.
4	Co. 213	do.	Yellowish B, hard	3·58	86·60	3·57	2·47	7·4 ,,	do
5	Co 213	Saidapur	Brown, sweet, hard	2·88	82·04	7·81	3·26	5 4 ,,	Improved method, lime water as clarifier
6	Co 213	Nanded	Soft, dark B	3·64	78·34	8·00	3·76	13·2 ,,	do
7	Co. 213	Mahboobnagar farm	Black with yellow tinge, sticky	5·95	70·93	8·65	4·81	8·6 ,,	Sajjikhar and *bhendi* juice as clarifier
8	Co. 213	Rudrur farm	Golden yellow, sweet and hard	1·93	78·73	10·00	2·44	7·00 ,,	do.
9	Co. 213	do	Reddish B, hard, saltish	1·90	85·63	5·86	4 26	11·5 ,,	Castor cake 1200 lbs $(NH_4)_2SO_4$ 75 lb.
10	Co. 213	do.	Golden yellow, hard, saltish	1·92	87 20	5·88	5·30	9·5 ,,	Castor cake 1600 lbs. $(NH_4)_2SO_4$ 100 lb.
11	Co. 213	do	Reddish B, sweet, hard	2·60	79·43	12 41	2·87	8·3 ,,	Castor cake 2000 lbs. $(NH)_2SO_4$ 125 lb.
12	Co. 213	do	Dirty B, sweet and hard	2·70	80·64	9·53	4·33	7·4 ,,	Castor cake 2400 lbs $(NH_4)_2SO_4$ 150 lb.
13	Co 213 regar soil	do.	Pale reddish B, sweet, hard	2 50	80·55	9 62	1·92	5·1 ,,	Planted on 15th January 1933
14	Co. 213 regar soil	do.	do	1·30	80·92	9 90	1·33	4·7 ,,	Planted on 15th February 1933
15	Co. 213 regar soil	do.	Golden yellow, sweet, hard	1·40	81·99	9·71	2·11	6·00 ,,	Planted on 15th March 1933

16	Co. 213 regar soil	do.	Golden yellow, sweet, not so hard	3·10	79·25	9·45	2·41	5·22 ,,	Planted on 15th April 1933
17	Co. 213 regar soil	do	Reddish B, sweet, hard	2·70	80·40	13·04	2·04	spoiled ,,	Planted on 15th November 1932
18	Co. 213 regar soil	do	Pale yellow, sweet, not so hard	3·20	76·75	16·88	2·65	2·5 ,,	Planted on 15th December 1932
19	Co. 213 chalka	do	Golden yellow, sweet, hard	1·70	73·80	10·84	2·67	4·4 ,,	Planted on 15th November 1932
20	Co. 213 chalka	do	do	1·50	77·71	11·07	1·88	3·1 ,,	Planted on 15th December 1932
21	Co. 213 chalka	do	do	1·60	80·86	11·97	2·25	4·7 ,,	Planted on 15th January 1933
22	Co. 213 chalka	do	do	1·20	72·39	10·95	2·23	6·1 ,,	Planted on 15th February 1933
23	Co. 213 chalka	do	do	1·20	74·55	11·44	1·53	3·00 ,,	Planted on 15th March 1933
24	Co. 213 chalka	do	Reddish B, sweet, hard	1·60	73·03	8·96	2·55	6·2 ,,	Planted on 15th April 1933
25	Co. 213 chalka	Parbhani	Dark B, burnt flavour, soft	4·90	79·28	12·56	4·35	3·2 ,,	Sajjeekhar, *bhendi* juice as clarifier
26	Co. 223	Himayat sagar farm	Reddish brown, soft, saltish	6·85	82·86	4·44	3·17	13·0 ,,	do.
27	Co. 223	do	Slightly saltish	7·17	82·00	3·84	3·16	9·8 ,,	do.
28	Co. 223	do	do	3·84	81·11	3·33	2·58	9·7 ,,	do.
29	Co. 223	do	Reddish brown, soft sweet	4·09	87·59	4·34	1·64	8·7 ,,	do.
30	Co. 223	Rudrur farm	Yellowish B, sweet, hard	[illegible]·00	72·20	15·37	3·32	8·0 ,,	do.
31	Co. 223	Parbhani farm	Dark B, burnt flavour, soft	3·50	80·35	11·44	4·22	3·3 ,,	do
32	Co. 281	Himayat sagar farm	Reddish brown, soft, slightly saltish	7·32	79·79	6·70	3·56	9·6 ,,	do.
33	Co. 281	do	do	4·67	83·37	5·46	2·30	8·4 ,,	do.
34	Co. 281	do	Dark brown hard, slightly saltish	[illegible]·63	74·39	2·70	2·75	7·8 ,,	do.
35	Co. 281	do	Yellowish brown, hard, slightly saltish	2·10	85·25	4·40	2·13	7·7 ,,	do.
36	Co. 281	Rudrur farm	Dark brown hard, sweet	2·10	80·55	9·62	1·73	5·5 ,,	do.
37	Co. 281	Parbhani farm	Reddish brown, soft, B flavour	4·00	77·10	7·36	4·84	3·8 ,,	do.

TABLE I—*contd.*

Analysis of 'Gur' samples from different localities of the State and Govt. farms, 1931—contd.

Serial number	Variety	Locality	Description	Moisture per cent	Sucrose per cent	Reducing sugars per cent	Ash per cent	Alkalinity in ash per 100 gms. sample	Remarks (clarifiers, manures, etc.)
38	Co. 290	Himayat sagar farm	Reddish brown, soft, sweet	5 83	80 26	5·68	4·06	1·6 N. Acid	Saj eekhar, *bhendi* juice as clarifier
39	Co. 290	do	do	6 67	83 88	6 53	3·16	8 1 ,,	do.
40	Co. 290	do.	do	6 73	84·49	5 88	3 47	8 4 ,,	do.
41	Co 290	do	Yellowish brown sweet, hard	3·34	74 46	6·48	2 81	8 6 ,,	do
42	Co 290	Rudrur farm	Dirty brown hard, sweet	3 50	76 40	15 60	2·95	8·3 ,,	do.
43	Co. 290	Parbhani farm	Dark brown, saltish, sour, soft	4 20	73 01	10·30	5 55	6·1 ,,	do
44	Poj. 2878	Himayat sagar farm	Yellowish brown, soft, sweet	4 75	86 24	5 71	2·35	7·5 ,,	do.
45	Poj 2878	do.	do	6 50	86 27	2 40	1·64	5 4 ,,	do
46	Poj. 2878	do	do	5 72	78·93	2 86	2 55	9 5 ,,	do.
47	Poj. 2878	do	Dark brown, hard, sweet	3 35	81 25	7·70	2 53	6 9 ,,	do.
48	Poj. 2878	Rudrur farm	Pale brown, sweet, hard	2 50	75 72	14 71	2 07	4 8 ,,	do
49	Poj. 2878	Parbhani farm	Reddish brown, soft, B flavour, contains much foreign matter	5·8	77 91	9 36	3 01	3 0 ,,	do.
50	Poj. 2714	Himayat sagar farm	Golden yellow, sweet, soft	6 70	86·43	3 25	2 20	5 8 ,,	do.
51	Poj. 2714	do	Yellowish B., sweet, slightly soft	4 77	85 52	4·16	1·86	8·9 ,,	do.
52	Poj. 2714	Rudrur farm	Golden yellow, sweet, hard	2 00	85 54	7·63	2·28	5 7 ,,	do.
53	Poj. 2725	do	Reddish brown, sweet very hard	1 30	86 46	8 37	1 60	4 5 ,,	do.
54	H. M. 544 (striped)	Himayat sagar farm	Reddish brown, sweet, soft	7 00	81·01	8 43	1 94	5 5 ,,	do.
55	H. M. 544 (striped)	do.	Yellowish brown, little soft, sweet	4 38	88·01	3 38	1 38	6·4 ,,	do.
56	H. M. 544 (striped)	Rudrur farm	Pale brown, sweet, hard	2 50	75·29	12·12	1·54	2·4 ,,	do.

57	H. M. 544 (unstriped)	Himayat sagar farm	Yellowish brown, soft, sweet	6·20	80·22	12·05	1·80	5·0 ,,	Sajjeekhar, *bhendi* juice as clarifier
58	H. M. 544 (unstriped)	do	do	6·20	83·45	5·60	1·60	4·7 ,,	do.
59	H. M. 544 (unstriped)	Rudrur farm	Brown, sweet, hard	3·00	72·02	14 11	2·01	3·1 ,,	do
60	H. M. 320	Himayat sagar farm	Brown, sweet, soft	5·43	87·36	6·25	1·72	6·1 ,,	do.
61	H. M. 320	do	Reddish brown, sweet, hard	3·95	84·04	4·76	1·52	6·9 ,,	do.
62	H. M. 320	Rudrur farm	Pale brown, sweet, hard	3·10	78 82	11·44	1·31	2·9 ,,	do
63	D. 109	Himayat sagar farm	Yellowish B, soft, sweet	4·35	82 66	7·81	2·40	3·8 ,,	do
64	D. 109	do.	do	6 92	89 72	3·77	1 70	6·7 ,,	do.
65	D. 109	Rudrur farm	Brown, sweet, hard	3 90	75·19	8·00	1·52	4·4 ,,	do
66	D. 109	Parbhani farm	Dark brown, soft, slightly burnt flavour	5·20	76·48	17·16	3·02	5·2 ,,	do
67	Fiji B.	Himayat sagar farm	Dark brown, sweet, hard	2·54	84·48	4·29	1·47	6·7 ,,	do.
68	Fiji B.	do.	do	3·17	90·58	4·65	0·84	4·0 ,,	do.
69	Fiji B.	Rudrur farm	Dirty brown, sweet, slightly soft	4·00	77·97	15·60	1·50	5·1 ,,	do.
70	E. K. 28	do.	Golden yellow, sweet, hard	1·86	76·50	10·84	1·62	4·2 ,,	do.
71	E. K. 28	Parbhani farm	Dark brown, soft, slightly sour	6·10	66 74	14·30	2·46	4·00 ,,	do.
72	Local cane	Usafwad, bid district	Brown, sweet, soft	8·14	80·49	10·10	1·43	5·8 ,,	No clarifier used
73	Local cane	Saidapur district	Brown, sweet, hard	2 82	83 11	9·35	3·20	4·5 ,,	Local method
74	Local cane	do.	Pale reddish, B, hard, sweet	3·06	81·72	7·52	3·31	7·9 ,,	Improved method
75	Local cane	Nanded	Reddish brown, hard, sweet	2·63	79·33	12·65	2·23	7·1 ,,	do.
76	Local white	Yadgir, district Gulbarga	Reddish brown, sticky, sweet	5·93	63·45	17·76	3·25	8 8 ,,	Lime used for clarification
77	Local white	do.	Dark brown, stricky, sweet	4·70	69·00	13·20	4·65	17·5 ,,	Ash as clarifier
78	Pundya	Gaugavati, district Raichur	Yellowish brown, soft, sweet	5·10	72·63	20·88	1·97	4·3 ,,	Improved method
79	Pundya	do.	Dirty dark brown, sweet, hard	2·71	79·81	7·36	2·51	6·1 ,,	Local method, scum not removed
80	Pundya	Parbhani farm	Reddish brow soft, sweet	4·00	63·46	17·75	3·10	3·9 ,,	Sajjeekhar, *bhendi* juice as clarifier

TABLE II

Comparison of alkalinity in 'gur' made from Coimbatore sugarcane varieties cultivated at Rudrur Govt. Farm, Nizamabad District, and Himayatsagar Main Farm, Hyderabad-Deccan

Expressed as normal c. c. acid required to neutralize alkalinity in ash of 100 gm. *'gur'*

Serial number.	Variety	Himayatsagar			Rudrur		
		1935-36	1936-37	1937-38	1935-36	1936-37	1937-38
1	Co. 205	..	6·80	4·8			.
2	Co. 213	4·8 to 7·2	3·80	5·8	1·7 to 3·2		2·4
3	Co. 219	.	6·40	..	.	..	..
4	Co. 223	2·6 to 4·9	6·60	4·0	1·7	1·1	1·0
5	Co. 244		4·80	1·2	.	.	
6	Co. 270	..	7·00	4·4	.	.	.
7	Co. 281	4·4 to 6·2	7·20	3·8	2·3	1·4	1·2
8	Co. 285	..	8·80	5·6	..	.	..
9	Co. 290	4·7 to 7·7	6·60	6·2	3·45	2·7	1·6
10	Co. 299	..	7·00	..	.	..	..
11	Co. 300	3·2 to 6·4	6·00	8·2	.	1·8	1·3
12	Co. 301	..	4·40	5·2	.	1·4	1·4
13	Co. 313	5·8 to 7·3	7·80	5·0	..	2·2	1·4
14	Co. 326	..	9·40	..	.	..	..
15	Co. 331	4·9 to 7·8	7·60	3·4	..	1·6	1·2
16	HM. 320	3·2 to 6·4	4·5	2·8	.	0·4	1·2
17	HM. 544	2·8 to 5·1	4·4		.	0·4	1·0
18	HM. 544 str.	..	5·4	..	1·9	1·6	1·2
19	HM. 608	..	5·8	4·0	.	.	..
20	HM. 613	..	7·0	5·8	..	..	..

TABLE—*contd.*

Serial Number.	Variety	Himayatsagar			Rudrur		
		1935-36	1936-37	1937-38	1935-36	1936-37	1937-38
21	HM 617	..	3·8	6·2	..	..	..
22	HM 627	..	6·0	4·2	..	..	..
23	Poj 2714	3·4 to 5·5	5·0	2·8	2·85	1·4	1·0
24	Poj 2725	..	3·3	4·0	..	0·6	1·6
25	Poj 2878	3·2 to 4·9	5·6	3·0	2·5	0·6	1·2
26	Poj 2883	..	7·4	..	..	0·7-3·0	0·8
27	D 109	.	5·4	..	..	1·1	1·6
28	Fiji B	.	5·4	..	..	1·2	0·8
29	Ek 28	2·8 to 3·1	6·6	3·2	3·25	0·6	1·6

TABLE III

Water soluble salts in soils and irrigation waters from Rudrur Government Farm, Nizamabad District, and Himayatsagar Main Farm, Hyderabad

Soluble salts in Rudrur chelka soils. (Red sandy loams)

Serial Number.	No. of plot	Parts per 100,000				SO_4
		Total salts	CO_3	HCO_3	Cl	
1	A5c	67	..	42·7	3·5	..
2	C11	62	..	30·5	7·0	..
3	A1a	136	..	73·2	17·5	..
4	A1c	80	..	48·8	7·0	..
5	A1b	84	..	48·8	10·5	..
6	A5b	124	..	73·2	7·0	..
7	C10	78	..	48·8	3·5	..
8	A2bc	126	..	73·2	3·5	..
9	A2a	68	..	30·5	7·0	..
10	A2bc	126	..	73·2	10·8	..

TABLE—*contd.*

Soluble salts in Himayatsagar cane soils. (Black clay loams)

Serial Number.	Parts per 100,000					SO_4
	No. of plot	Total salts	CO_3	HCO_3	Cl	
1	A	110	..	73·2	3·5	..
2	B	120	..	73·2	7·0	..
3	C	114	..	67·1	5·25	..
4	D	68	..	30·5	5·25	..
5	E	80	..	42·7	7·0	..
6	F	130	..	79·3	5·25	..

Salts in waters

Serial Number	Source of irrigation	Location of sampling	Parts per 100.000				
			Total salts	CO_3	HCO_3	Cl	SO_4
1	Nizamsagar canal	Rudrur farm . .	14·2	3·2	5·4	1·05	..
2	Nizamsagar canal	Rudrur, outside farm .	13·1	..	8·2	1·05	..
3	Nizamsagar canal	Near Varni Nizamabad	11·8	2·7	5·4	0·70	..
4	Himayatsagar canal	Himayatsagar farm .	21·1	1·8	12·2	1·05	..

TABLE IV

Alkalinity in 'gur' made from plant and ratoon sugarcanes of Coimbatore varieties cultivated at Himayatsagar Main Farm

Serial Number.	Variety	Alkalinity in ash from 100 gms. *gur* expressed as c.c.N. acid and taste					
		1933-34 new crop	1934-35 Ratoon	1934-35 new crop	1935-36 Ratoon	1935-36 new crop	1936-37 Ratoon
1	Co. 213 a	13·5 slt	5·0 sw	7·4 ssl	5·5 sw	4·8 sw	4·0 sw
2	Co. 213 b	11·9 slt	5·6 sw	8·7 ssl	4·9 ssl	6·8 sw	4·6 sw
3	Co. 213 c	8·1 slt	4·4 sw	5·6 sw	4·6 sw	7·2 ssl	5·0 sw
4	Co. 213 d	7·4 slt	5·6 sw	7·6 sw	3·2 sw	6·4 sw	5·9 slt
5	Co. 213 e	..	..	..	..	6·0 ssl	4·6 ssl
6	Co. 213 f	..	..	..	..	6·1 sw	3·9 ssl
7	Co. 223 a	13·0 slt	3·5 sw	9·6 sw	4·0 ssl	4·7 slt	3·4 sw
8	Co. 223 b	9·8 slt	5·1 sw	9·2 sw	3·4 slt	2·6 slt	3·0 sw
9	Co. 223 c	9·7 slt	3·1 sw	7·3 sw	4·3 ssl	4·8 sw	4·2 sw
10	Co. 223 d	8·7 sw	4·3 sw	7·3 ssl	4·4 sw	4·3 ssl	2·6 sw
11	Co. 223 e	..	..	..	..	4·6 ssl	6·2 sw
12	Co. 223 f	..	..	..	..	4·9 ssl	3·8 ssl
13	Co. 281 a	9·6 slt	4·8 sw	6·4 sw	3·2 slt	5·1 slt	3·8 sw
14	Co. 281 b	8·4 slt	4·4 sw	5·6 sw	3·6 slt	6·2 slt	3·4 sw
15	Co. 281 c	7·8 slt	3·6 sw	7·2 sw	3·1 sw	4·3 slt	3·2 ssl
16	Co. 281 d	7·7 ssl	3·4 slt	6·2 sw	3·9 slt	4·0 sw	4·6 sw
17	Co. 281 e	..	..	..	..	4·5 slt	3·0 sw
18	Co. 281 f	..	..	..	..	4·7 slt	2·1 ssl
19	Co. 290 a	1·6 sw	2·7 sw	7·2 ssl	2·8 slt	5·1 ssl	3·8 sw
20	Co. 290 b	8·1 sw	4·7 slt	4·8 sw	5·3 slt	6·6 ssl	4·8 ssl
21	Co. 290 c	8·4 sw	3·5 slt	7·8 ssl	7·0 slt	7·7 ssl	5·8 ssl
22	Co. 290 d	8·6 sw	2·9 slt	4·8 ssl	3·4 slt	7·4 slt	5·3 slt
23	Co. 290 e	..	..	..	..	4·7 slt	5·8 slt
24	Co. 290 f	..	..	..	..	7·4 slt	3·4 slt

ssl = slightly saltish slt = saltish sw = sweet

TABLE V

Alkalinity and taste of 'gur' samples of 20 leading varieties under trial at the Main Farm Himayatsagar, Hyderabad, for three years

Serial Number.	Variety	Alkalinity			Taste		
		c.c.N. acid required for ash in 100 grams '*gur*'			Line tests : 6 lines for each variety		
		1936-37	1937-38	1938-39	1936-37	1937-38	1938-39
1	Co. 419	8·7	3·8	3·6	S.St.	S.St.	Sw.
2	Co. 423	5·6	4·4	4·9	S.St.	S.St.	Sw.
3	Co. 426	5·6	4·4	3·9	S.St.	St.	S.St.
4	Co. 434	6·0	6·0	4·4	Sw.	S.St.	Sw.
5	Co. 524	..	..	4·3	..	..	S.St.
6	Co. 523	..	..	4·4	..	..	Sw.
7	Co. 421	5·4	5·8	5·4	Sw.	Sw.	Sw.
8	Co. 301	4·4	5·2	4·1	St.	Sw.	S.St.
9	Co. 520	..	..	4·6	..	..	S.St.
10	Co. 290	6·6	6·2	4·5	S.St.	St.	St.
11	Co. 511	5·6	4·6	4·6	St.	Sw.	Sw.
12	Co. 413	5·1	3·8	3·9	St.	Sw.	S.St.
13	Co. 530	..	..	6·6	..	..	Sw.
14	Co. 408	3·5	3·2	6·1	Sw.	S.St.	Sw.
15	Co. 244	4·8	4·2	4·9	Sw.	S.St.	S.St.
16	Co. 513	7·8	5·4	6·9	St.	S.St.	St.
17	Co. 331	7·6	3·4	5·8	St.	Sw.	S.St.
18	Co. 429	7·8	4·8	6·5	Sw.	Sw.	Sw.
19	Co. 509	6·6	5·4	6·2	Sw.	Sw.	Sw.
20	Co. 313	7·8	5·0	4·9	Sw.	S.St.	Sw.

St.=Saltish S.St.=Slightly saltish Sw.=Sweet

TABLE VI

Statement showing the analysis of 'gur' samples together with their taste for sugarcane varieties under trial at the Government Agricultural Experiment Station. Himayetsagar. Hyderabad Dn. for the year 1939-43

Serial Number.	Variety	Taste				Per cent chlorine (Cl′)				Per cent sulphate (SO₄″)				Alkalinity (c.c. of normal required for 100 gm. *gur*)			
		1939-40	1940-41	1941-42	1942-43	1939-40	1940-41	1941-42	1942-43	1939-40	1940-41	1941-42	1942-43	1939-40	1940-41	1941-42	1942-43
1	Co 244	Sweet	Saltish	Saltish	Sweet	0·34	0·59	0·60	0·58	0·54	0·44	0·61	0·42	5·4	9·3	8·2	11·3
2	Co 290	Saltish	Saltish	Highly Saltish	Saltish	0·60	0·82	0·96	0·73	0·59	0·46	0·60	0·40	4·9	7·2	6·4	9·3
3	Co 301	Saltish	Saltish	Saltish	Saltish	0·57	0·50	0·50	0·72	0·75	0·54	0·76	0·58	4·6	12·5	8·3	11·5
4	Co .313	Saltish	Saltish	Saltish	Saltish	0·64	0·57	0·66	0·69	0·56	0·54	0·64	[illegible]	6·0	11·6	9·7	13·0
5	Co 331	Saltish	Saltish	Highly Saltish	Saltish	0·56	0·57	0·70	0·68	0·75	0·49	0·77	0·61	3·6	13·9	4·4	8·8
6	Co 408	Sweet	Sweet	Saltish	Saltish	0·39	0·37	0·48	0·42	0·64	0·40	0·72	0·49	2·7	6·5	4·6	5·2
7	Co. 413	Saltish	Saltish	Saltish	Sweet	0·56	0·60	0·59	0·45	0·54	0·57	0·52	0·41	6·7	10·8	15·4	8·5
8	Co. 419	Sweet	Sweet	Sweet	Sweet	0·35	0·33	0·41	0·35	0·45	0·50	0·51	0·42	3·0	3·6	5·0	9·4
9	Co 421	Sweet	Saltish	Sweet	Sweet	0·47	0·57	0·19	0·36	0·59	0·58	0·29	0·54	4·5	12·1	5·4	10·0
10	Co 423	Saltish	Indifinite	Sweet	Sweet	0·60	0·52	0·20	0·59	0·86	0·53	0·23	0·51	4·5	9·5	5·1	10·7
11	Co 426	Saltish	Saltish	Saltish	Sweet	0·45	0·58	0·58	0·47	0·58	0·43	0·61	0·50	4·4	10·6	4·6	7·6
12	Co. 434	Sweet	Indifinite	Sweet	Sweet	0·45	0·45	0·46	0·53	0·86	0·43	0·46	0·39	5·0	8·4	5·5	9·5
13	Co. 513	Saltish	Saltish	Highly Saltish	Saltish	0·95	0·67	0·80	0·81	0·67	0·61	0·70	0·49	4·1	10·7	7·6	12·0
14	Co 520	Sweet	Saltish	Indifinite	Sweet	0·43	0·47	0·46	0·46	[illegible]	0·52	0·59	0·57	4·1	9·8	6·1	11·5
15	Co. 523	Sweet	Saltish	Saltish	Sweet	0·38	0·58	0·49	0·51	0·59	0·62	0·81	0·61	5·2	10·0	5·7	10·2
16	Co. 524	Indifinite	Sweet	Saltish	Saltish	0·50	0·46	0·53	0·61	[illegible]	0·56	0·70	0·57	5·7	12·4	[illegible]	19·1
17	Co 530	Indifinite	Sweet	Sweet	Sweet	0·50	0·37	0·34	0·43	0·55	0·56	0·69	0·48	5·8	9·9	8·4	15·1
18	Co 532	Saltish	Indifinite	Saltish	Indifinite	0·63	0·46	0·53	[illegible]	0·61	0·58	0·44	0·33	3·1	5·3	6·8	11·4

N.B.—The results are averages of four replications

REVIEWS

CHEMICAL COMPOSITION OF PLANTS AS AN INDEX OF THEIR NUTRITIONAL STATUS

By D. W. Goodall and F. G. Gregory

(Published by the Imperial Bureau of Horticulture and Plantation Crops, August, 1947. pp. 167 and bibl. 936. Rs. 9)

THIS is a monograph full of closely packed information, in which the authors have attempted to estimated the value of plant-analysis methods with the critical acumen, necessary for successful research. The results of previous workers have also been carefully collected and assembled in a manner of great usefulness.

It is often claimed that the composition of the plant reflects its nutritional status. the adequacy of nutritional supplies and the probability of its response to increased supplies. The examination of these claims forms the principal topic of this highly useful monograph, the ultimate object of which, is to obtain a solution of the central problem. the determination of fertilizer requirements. The book starts with an introductory review of the different methods of assessing fertilizer requirements and a detailed consideration of the various methods, which have been proposed and attempted, finally coming to the use of plant-analysis and comparison of the value with those of other techniques.

There are in all 15 Tables, of which, Table I extends over 16 pages, giving the published data of the content of nutrients in plants, showing symptoms of nutritional disorder. These have been reproduced in summary forms and contrasted with data for otherwise comparable forms not showing the symptoms. Similarly, Table II gives the limiting value, below which, deficiency symptom and above which, toxicity symptoms may occur. Another Table (Table XII), gives the standard values of 'nutrients content' proposed in the literature. These are as much interesting as useful.

The 'author-index' covers over 800 entries. The bibliography gives the titles and references of the papers and publications, whereas, the 'subject-index' and 'author-index' are put up separately. The arrangement thus facilitates easy reference.

The correct criterion for assessing the value of any method for the fertilizer requirements depends on the accuracy with which the response to fertilizer additions can be forecast. The pre-requisite for it is, a series of comprehensive experiments in which the samples of plant material have to be taken for analysis before the

fertilizers, whose effects are to be predicted, are applied. The chemical composition of the plant, if estimated at the right stage, offers a great saving of labour, besides the fact, that the results can be obtained with very little delay. This has prompted the authors to give a general survey of the use of plant analysis for diagnostic purpose showing the main lines of development during the last two decades. Here 'tissue tests' methods deserve special mention on account of the rapidity with which it enables determination of the deficiency. The theory behind this method is based on the natural probability that the nutrients present in the conducting tissues consist largely of unassimilated materials and hence their concentration will represent their current rate of intake. The senior author, in particular, has done considerable work relating to the diagnosis of mineral dificiency. The 'tissue tests' method holds out great promise and needs to the tried on a still wider scale.

The book is an epitome of great care, erudition and labour, and will be of great service to all research workers.

Incidentally, it reveals how little work on these important aspects have been conducted in India. (I.C.)

FARM SCIENCE AND CROP PRODUCTION IN INDIA

By C. P. Dutt and B. M. Pugh

(Published by Kitabistan, Allahabad, 1947, pp. 240, Rs. 12)

THIS is the second edition of the book but the original name 'Crop Production in India' has been somewhat modified.

As in the first edition, the book is divided into two parts but here also the title has been changed. Part I has been named 'Farm Science' in place of 'General Pro-principal of Crop Production,' and Part II 'Crop Production in India' in place of 'Field Crops'. Both parts have been separately paged. The more welcome change in the book is its size which has now become handier, smaller and lighter. The portions dealing with statistical method and laying out of field experiments have been deleted. The older data on crop and other statistics have been replaced by newer ones 1941 but it would have been more helpful if the more recent data on the basis of Indian Union and Pakistan had been included. Such data are available. Another omission here is that whereas the newer statistics have been taken largely from 1941 data, the corresponding correction has not been made in the bibliography under the different chapters where generally the reference is to the older publication asgiven in the first edition. In Table V, page 33 some of the botanical names are older ones. They differ from those given in the *Kew Bulletin* by Sampson. They

should be suitably corrected. In this Table 'common names' have been given. It would have helped the readers of the different provinces if the important vernacular names had been included either here or separately in the chapter dealing with individual crops.

In part II, page 14, the total estimated yield of wheat has been given at 12 million tons (324 million md.). On the other hand in Table III, page 11 the production of wheat has been shown at 257·275 million md. Evidently both these data have been taken from different sources or possibly there is some error. Similar checking is also needed in the case of other data and as they are of very great importance the author's attention is invited to them.

Under maize there is no mention about the recent development on hybrid maize. Under minor oilseeds mustard crop has been included. I do not know on what ground it has been considered as minor oilseed as both mustard and mustard oil are of major importance all over Northern India.

The authors have produced a useful book but it would have been much better if they had confined their attention to the main aspect of crop production instead of attempting rather too many things.

In citing references the authors should do it on the basis of latest books and periodicals. Here too there is much room for improvement. (I. C.)

CENTRAL BOARD OF IRRIGATION NOTIFICATION

THE CENTRAL BOARD OF IRRIGATION MEDAL RULES

THE C.B.I. Medal has been instituted to encourage research relating to and the technique and development of the water resources of India and all devices and matters connected therewith.

The Medal will be awarded at the annual meeting of the Board to a person (or persons) whose contribution to research (basic or applied) technique, theory or practice relating to the development of the water resources of India is adjudged by the Executive Committee of the Board to be an outstanding original contribution of the preceding year.

The year for purposes of award of the medal will be the calendar year.

The contribution may be in the form of a paper presented to the annual meeting of the Research Committee of the Central Board of Irrigation or to any other engineering institution in India or may be an article published for the first time in the C.B.I. Journal or any other technical journal published in India.

Applications for the award should be addressed to the Secretary, Central Board of Irrigation, Kennedy House, Simla 4, so as to *reach him before the 1st March**, each year and unless the paper or article has been presented to the C.B.I. Research Committee or published in the C.B.I. Journal, the application should be accompanied with five copies of the article or paper.

The merit of the award shall be adjudged by and at a meeting of the Executive Committee of the C.B.I., which is usually held at the time of the annual Research Committee meeting. The decision of the Executive Committee will be final and binding on the applicants. No correspondence will be entered into with regard to the decision of the Executive Committee and this is a necessary condition of entries in the competition.

In case no contribution is considered to be of the requisite high standard from among those which enter the competition, the Executive Committee may decide not to make any award in a particular year.

*For paper and article published during the year 1948, the date has been extended to 30th April, 1949.

MGIPC—M—III-1-25—2-2-50—600.

ORIGINAL ARTICLES

DETERMINATION OF THE MATURITY COEFFICIENT FOR INDIAN COTTONS

By R. L. N. Iyengar, D.Sc., and Nazir Ahmad,* Ph.D., F. Inst. P.

Indian Central Cotton Committee, Technological Laboratories, Bombay

(Received for publication on 20 April 1948)

(With four Text-figures)

THE original cell-diameter of the cotton fibre is the real measure of its fineness. In order to estimate this character various properties like the ribbon-width, swollen diameter, mercerised diameter and fibre weight per unit length are employed. Among them the fibre weight per unit length is the most easily determinable quantity. Unfortunately however, its efficiency as a criterion for fineness is vitiated by the variation of the maturity of the fibres composing the sample. For example a coarse cotton having a considerable proportion of immature fibres may give the same or sometimes smaller fibre weight per unit length than a fine cotton whose fibres are mostly mature. In order to overcome this defect in the fibre weight, Peirce and Lord [1934] conceived the idea of the 'maturity coefficient', by means of which proper weightage is given to the fibres falling within the three maturity classes. The observed fibre weight per unit length when divided by the maturity coefficient gives an expression characteristic of the strain of cotton independent of fibre-maturity. Peirce and Lord [1934] called this quantity the 'normal-hair-weight' and the square root of this quantity is proportional to the original cell-diameter of the cotton fibre. The use of the constants derived by these authors to calculate this attribute in the case of the work done in India is open to two objections, namely, (i) not many Indian Cottons were included among those studied by Perice and Lord [1934 and 1939] and (2) the method of determining the fibre-maturity generally employed in India [Gulati and Ahmad, 1935] is somewhat different from the method employed by these authors, viz., Clegg's [1932] method. It is, therefore, necessary that for the Indian work the constants should be determined separately. This is the object of the present investigation.

Material

As already stated constants have to be obtained in order to correct the values of the fibre weight for the variation due to fibre-maturity. The material has, therefore, been chosen with a view to have the widest possible range of fibre-maturity. Among the 22 strains of cotton selected, the maturity ranged from the low value of 9-22-69 to the high value of 85-10-5. The details of the samples are recorded in Table I.

*At Present Economic Adviser to the Government of Pakistan.

TABLE I

Details of cottons studied

Cotton	Botanical species	Season	Place of growth	Fibre-maturity per cent			
				Mature	Half-mature	Immature	Fibre weight per cm. in 10^{-6} gm.
1. 3915F	G. Hirsutum	1939-40	Indore	9·0	22·4	68·6	1·00
2. LSS	G. Hirsutum	1940-41	Lyallpur	15·6	16·8	67·6	0·98
3. 100F	G. Hirsutum	1938-39	Lyallpur	17·6	14·6	67·8	0·91
4. Sind sudhar	G. Hirsutum	1940-41	Sakrand (Sind)	18·6	15·8	65·6	0·92
5. 4F	G. Hirsutum	1938-39	Lyallpur	18·8	25·8	55·4	1·29
6. Perso American	G. Hirsutum	1938-39	Cawnpore	22·6	23·6	53·8	1·20
7. 47F	G. Hirsutum	1937-38	Lyallpur	37·8	22·6	39·6	1·39
8. 3915 Q	G. Hirsutum	1937-38	Coimbatore	41·8	19·2	39·0	1·28
9. Kampala (commercial)	G. Hirsutum	1941-42	East Africa	48·4	24·6	27·0	1·62
10. Verum 262	G. Arb. neg. Beng.	1938-39	Nagpur	50·0	26·6	23·4	1·54
11. Koilpatti 1	G. Arb. neg. Ind.	1938-39	Koilpatti	50·6	20·0	29·4	1·73
12. 1027 A.L.F.	G. Herbaceum	1938-39	Surat	54·2	28·0	17·8	2·46
13. California (commercial)	..	.	U.S.A.	56·6	21·6	21·8	1·60
14. Jarila	G. Arb. neg. Beng	1937-38	Jalgaon	56·6	22·2	21·2	1·78
15. Gadag 1	G. Hirsutum	1938-39	Dharwar	70·8	21·2	8·0	1·68
16. Sakels Saki (Commercial)	G. Barabadensis	1938-39	Egypt	72·4	19·0	8·6	1·27
17. Jayawant	G. Herbaceum	1938-39	Dharwar	74·8	17·4	7·8	2·30
18. Hagari 1	G. Herbaceum	1938-39	Hagari	74·8	16·8	8·4	2·17
19. Nandyal 14	G. Arb. neg. Ind.	1938-39	Nandyal	76·0	12·4	11·6	2·01
20 Gaorani 12F	G. Arb. neg. Ind.	1940-41	Hyderabad	77·4	12·0	10·6	2·26
21. Verum 434	G. Arb. neg. Beng.	1938-39	Akola	79·0	12·8	8·2	2·17
22. Mollisoni	G. Arb. neg. Beng.	1938-39	Lyallpur	85·0	10·0	5·0	2·93

It will be noticed that the cottons have been arranged in the ascending order of fibre-maturity and are divided into three groups. The first group contains cottons of low fibre-maturity, the second those of medium maturity while the third group contains cottons of high maturity. This division should not be taken to mean that any standards of fibre-maturity have been prescribed for purposes of classification. A glance at the maturity figures reveals that the cottons automatically divide themselves into the three groups, the limits being quite arbitrary. It will also be noticed that the samples chosen, besides having the wide range of fibre-maturity possible, also represent the range of cottons cultivated in India, from the

point of view of the botanical species and of the place of growth. Three foreign cottons A. R. Kampala, California and Sakels Saki are included in the study in order to see how the results obtained for these cottons compared with those for the Indian cottons.

It should not be misunderstood that some of the low values of fibre-maturity recorded in Table I for some of the cottons is a general feature for these cottons. In fact, they are some abnormal values and as we required cotton samples having low fibre-maturity, these samples were chosen.

Experimental procedure

A representative sliver was prepared out of the sample of lint and a tuft of about 500 fibres was pulled out from it and kept on a piece of plush. Fibres from this tuft were taken out and mounted on a slide parallel to one another and perpendicular to the length of the slide using seccotine. Twenty fibre were mounted on each slide and a wide gap was left after each group of five fibres so that the rank of the fibre under examination could be easily known at any stage. The fibres were fairly stretched while mounting and a thin layer of Dunlop rubber solution was smeared over the ends of the fibres, as otherwise the binding action of the seccotine would be weakened by contact with the caustic soda solution. A long cover-slip five millimeters wide was used to cover the fibres.

The fibres were first viewed in the raw state under polarised light by the method developed by Schwarz and others [1935 and 1938] and the maturity class of each fibre was recorded. They were then irrigated with eighteen per cent caustic soda solution and the maturity class of each fibre according to Gulati and Ahmad's [1935] method was also noted. In the beginning the allocation of the maturity class according to the polarised light method and the swelling method showed some divergence for some of the fibres lying on the borderland. But after some experience this number was reduced to about ten out of the 500 fibres examined for each cotton. Next the diameter of the fibre and the diameter of the lumen at the same place were recorded at five random places nearly equally apart along the five mm. length of the fibre under the coverslip.

As the fibres were originally fairly stretched, the contraction caused by the swelling in the alkali solution stretched them still further so that the fibres appeared like straight cylinders or tubes of different wall-thickness depending upon the degree of maturity of the fibre, the lumen also being clearly visible. The diaphragm of the microscope was made as small as possible and the condenser lens was lowered to the required extent to make the definition of the image of the fibre and the lumen very clear so that the measurements could be made quite accurately.

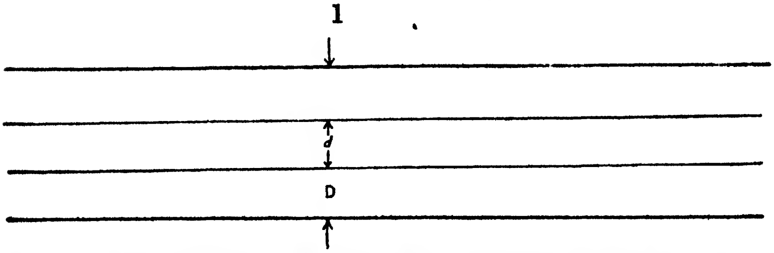


FIG. 1. Longitudinal section of a swollen cotton fibre which is partially thickened

THEORETICAL BASIS

If D is the diameter of a fibre and d the diameter of its lumen as shown in Fig. 1 volume of the cellulose inside unit length of the fibre is given by $\frac{\Pi}{4}(D^2-d^2)$. If no lumen were present, as in the case of a fully mature fibre, the volume of the cellulose would have been $\frac{\Pi}{4}D^2$. The ratio of the two is $\frac{D^2-d^2}{D^2}$ or $1-\frac{d^2}{D^2}$. This expression is the maturity coefficient of the fibre under consideration expressed in terms of the volume of cellulose. The same expression would stand in terms of the weight of cellulose also, if the weight of cellulose in unit volume of the swollen cellulose were constant in all the different types of fibres. *A priori* reasoning, however, indicates that this cannot be the case, for while inside the immature and half-mature and some of the mature fibres the lumen space provides room for the expansion of the swollen cellulose, inside mature fibres having no lumen, there is no such space for expansion. In the latter case, therefore, the cellulose should be under greater pressure and consequently having a greater 'density'* than in the case of the other fibres. It is, however, not possible to determine the 'density' in each individual fibre but the average value for each maturity class may be estimated, the method of doing which will be described later.

It was stated earlier that the maturity class of each fibre was recorded. For the fibres falling within the mature class the individual values of $1-\frac{d^2}{D^2}$ could be grouped together and their mean value, α, calculated. After similar grouping the mean values of the ratio for the half-mature class, β, and for the immature class, γ, could be obtained. These values, as already stated before, require correction for the change in the 'density' of cellulose and after applying the necessary corrections the respective values α, β and γ could be determined. If M, H and I are the percentages of the mature, half-mature and immature fibres respectively in the sample, the maturity coefficient is given by

$$M_c = \frac{\alpha M+\beta H+\gamma I}{100} \tag{1}$$

*The expression 'density' of cellulose used in this paper means the weight of cellulose only per unit volume of the swollen cellulose.

By dividing the fibre weight by this coefficient we get the weight of a mature fibre in which the lumen is completely absent. If, on the other hand, our basis is what we normally call a mature fibre, then α may be taken as the unit, when the maturity coefficient would be changed to

$$M_c = \frac{M+\beta/\alpha H+\gamma/\alpha I}{100} \tag{2}$$

The method of calculating the 'density' of cellulose inside the swollen mature, half-mature and immature fibres may now be considered. As already stated before $\frac{\Pi}{4}(D^2—d^2)$ gives the volume of cellulose inside a unit length of the fibre.* If ρ is the 'density' of cellulose, then the weight of the cellulose is $\frac{\Pi}{4}(D^2—d^2)$.

The mean value of this expression for all the 500 fibres examined should give the mean weight of cellulose per unit length for the sample of cotton under study. This quantity could be obtained in another way from the fibre weight which, for this purpose, was determined by weighing 2,000 fibres for each sample. As in the present study the central region of the fibre was used for diameter measurements, centimeter lengths cut from the middle of the fibres were used for weighing also. It is well known that the weight of the fibre is made up of cellulose, moisture, mineral matter, wax, etc. According to Marsh and Wood [1942] 'some typical data on the constituents of raw cotton are 90 per cent of cellulose, eight per cent of moisture, one per cent of mineral matter, 0·5 per cent of wax, etc., and 0·5 per cent of pectic matter' and these values can be taken as approximately true for Indian cottons also. In the present work as the fibre weight has been corrected to 70 per cent R.H. the moisture content practically corresponds to eight per cent stated above and therefore, 90 per cent of the fibre weight may be taken as equivalent to the weight of the cellulose. Of course this percentage may vary a little from cotton to cotton but on the average the variations may balance one another so that they do not influence the final conclusions. If the value of the cellulose weight per cm. is taken as 0·9F, where F is the fibre-weight per cm., then

$$\frac{\Pi}{4}(D^2—d^2)\,\rho=0{\cdot}9F \tag{3}$$

Or

$$\rho=\frac{3{\cdot}6F}{\Pi\,(D^2—d^2)} \tag{4}$$

From equation (4) the value of ρ could be calculated. If ρ_M, ρ_H and ρ_I are the mean values of ρ for the mature, half-mature and immature fibres respectively

* As the fibre is held stretched there is no contraction in length due to the action of caustic soda.

and since M, H and I are the percentages of the respective class of fibres, it may be stated that

$$\rho = \frac{M\,\rho_M + H\,\rho_H + I\,\rho_I}{100} \qquad (5)$$

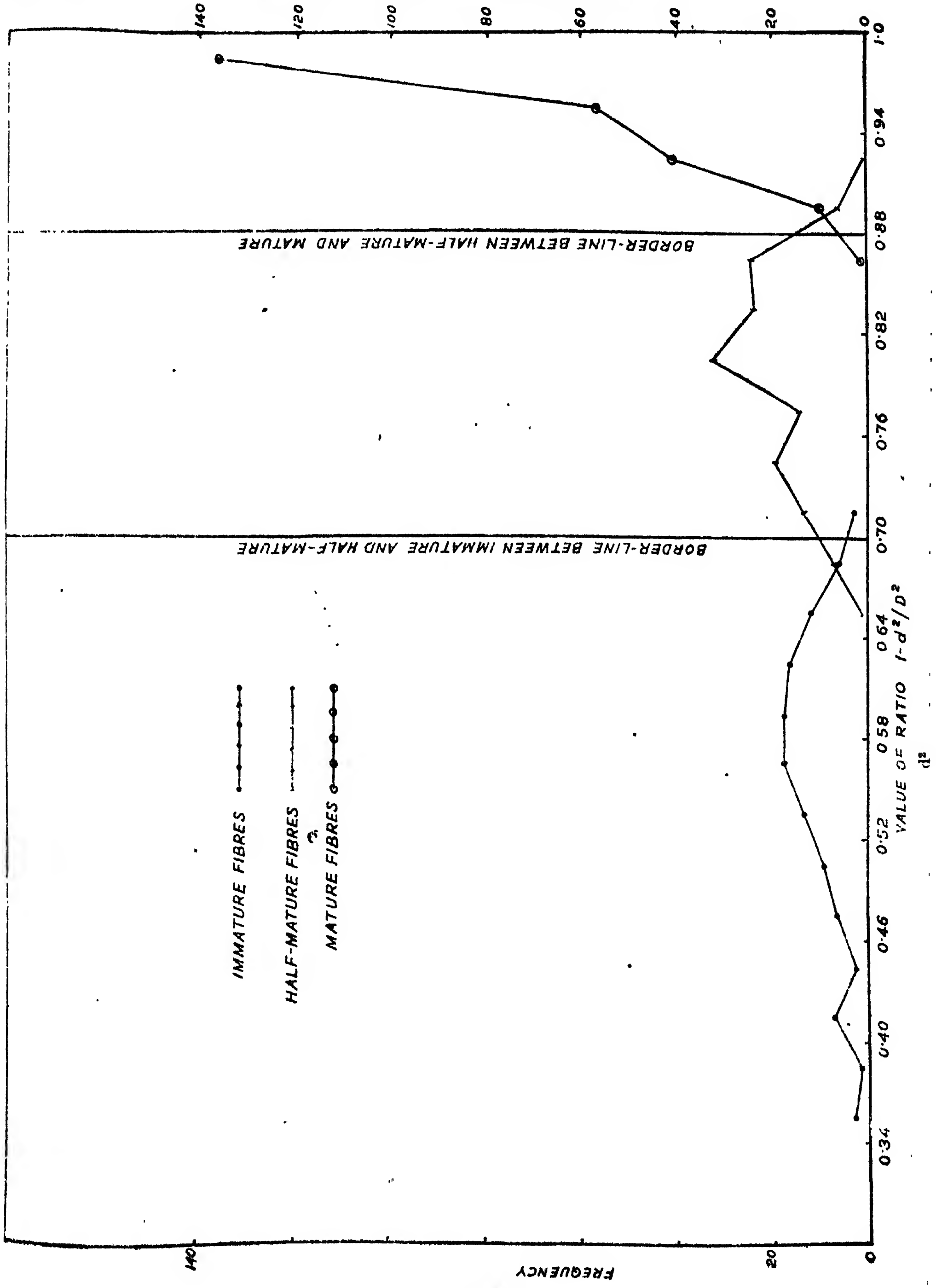
Such equations are obtained for each of the 22 cottons examined and from the 22 equations, employing the usual partial regression method, Fisher [1936], taking ρ as Y and M, H and I as X_1 X_2 and X_3 respectively, the values of ρ_M, ρ_H and ρ_I could be calculated. These values were found to be 0·52 gm. per c.c. for the mature fibres, 0·36 for the half-mature fibres and 0·38 for the immature fibres. It will be noticed that the value for the mature fibres is considerably higher than that for the other two, the difference between which is almost negligible. This finding, it will be remembered, is the same as what was anticipated previously from *a priori* considerations. As the value of ρ for both the latter classes of fibres is found to be nearly the same, it would be more appropriate to take the mean value for both the classes which we may call ρ_{HI}. A more correct estimate of this quantity could, however, be obtained by dividing the fibres into two classes only, namely, the mature and non-mature, when equation (5) would be modified into

$$\rho = \frac{M\,\rho_M + (100\text{-}M)\,\rho_{HI}}{100} \qquad (5a)$$

The values of ρ_M and ρ_{HI} obtained from the 22 such equations were found to be 0·52 and 0·38 respectively. It will be observed that the former value is the same as that got before while the latter differs from the previous value by 0·01 only. The present value, being the more correct one, has been used in all the calculations.

Results

(a) *Ratio $1-d^2/D^2$: Distribution in each maturity class.*—It was stated above that the ratio $1-d^2/D^2$ represents the maturity coefficient of the fibre in terms of the volume of the swollen cellulose. It is first necessary to determine the values of this ratio that correspond to the border lines between the mature and half-mature fibres and between half-mature and immature fibres. This is done as follows. It was already mentioned that the maturity class of each fibre was recorded following the method of Gulati and Ahmad [1935]. The values of the ratio $1-\frac{d^2}{D^2}$ for all the fibres falling within the mature class are grouped together; similarly, those for the fibres within the half-mature and immature classes respectively are also grouped. The data obtained in the case of medium mature cotton, Verum 262, are shown in Fig. 2. It will be seen that for the immature fibres the values range from 0·34 to 0·73, for the half-mature fibres from 0·64 to 0·94 and for the mature fibres from 0·85 to 1·0. The border lines are not clearly defined as there is some overlapping in these regions. This is bound to be the case as the estimation of


BORDER-LINE BETWEEN HALF-MATURE AND MATURE
BORDER-LINE BETWEEN IMMATURE AND HALF-MATURE
IMMATURE FIBRES
HALF-MATURE FIBRES
MATURE FIBRES
VALUE OF RATIO $1-d^2/D^2$
FREQUENCY
0·34
0·40
0·46
0·52
0·58
0·64
0·70
0·76
0·82
0·88
0·94
1·0
0
20
40
60
80
100
120
140

the fibre-maturity is of a subjective nature. However, after the examination of similar curves for a number of cottons it was possible to state with a fair amount of certainty that the border line between the immature and the half-mature fibres is 0·70 and that between the half-mature and the mature fibres is 0·88. That means that the values of the ratio up to 0·700 correspond to the immature fibres, those from 0·701 to 0·880 to the half-mature fibres while those from 0·881 to 1·0 correspond to the mature fibres. Using these ranges of the ratio the fibre-maturity values have been obtained in the present study. It is clear that this method of determining fibre-maturity is free from subjective error.

It will be noticed that in the case of the cotton V. 262 considered above (Fig. 2) the number of values of the ratio that do not conform to this range is few, 20 out of the 500 fibres examined, that is four per cent. This value is one of the higher levels recorded and in most of the cottons it was much less.

(b) *Ratio $1-d^2/D^2$: Mean value for each maturity class.*—From the data grouped into the three maturity classes the mean value of the ratio for each maturity class could be calculated. But as this represents the ratio in terms of the volume of the swollen cellulose, it is not of much use by itself. If, however, it is corrected for the change in the cellulose 'density', the ratio in terms of the weight of cellulose would be obtained. These corrected values are recorded in Table II.

TABLE II

Corrected mean values of the ratio $1-\dfrac{d^2}{D^2}$ for different maturity classes

Serial Number	Cotton	Maturity per cent	Mature	Half mature	Immature
1	3915F (Indore)	9-22-69	0·930	0·550	0·400
2	LSS	16-17-67	0·945	0·562	0·379
3	100F	18-14-68	0·934	0·558	0·371
4	Sind Sudhar	19-16-65	0·947	0·562	0·402
5	4F	19-26-55	0·944	0·562	0·388
6	Perso American	23-23-54	0·950	0·560	0·406
	Mean	..	0·9417	0·5590	0·3910
7	47F	38-23-39	0·960	0·565	0·374
8	3915 Q	42-19-39	0·966	0·548	0·395
9	A. R. Kampala	48-25-27	0·944	0·566	0·429
10	Verum 262	50-27-23	0·966	0·565	0·403

TABLE—*contd.*

Corrected mean values of the ratio $1-\frac{d^2}{D^2}$ *for different maturity classes*

Serial Number	Cotton	Maturity per cent	Mature	Half mature	Immature
11	Koilpatti 1	51-20-29	0·973	0·577	0·375
12	1027 A.L.F.	55-28-17	0·962	0·578	0·399
13	California	57-21-22	0·950	0·565	0·427
14	Jarila	57-22-21	0·961	0·575	0·395
	Mean	..	·09602	0·5669	0·3999
15	Gadag 1	71-21- 8	0·954	0·582	0·448
16	Sakel's Saki	72-19- 9	0·955	0·585	0·443
17	Jayawant	75-17-8	0·953	0·585	0·408
18	Hagari 1	75-17- 8	0·960	0·578	0·422
19	Nandyal 14	76-12-12	0·964	0·580	0·416
20	Gaorani 12F	77-12-11	0·968	0·573	0·429
21	Verum 434	79-13- 8	0·975	0·585	0·445
22	Mollisoni	85-10- 5	0·966	0·576	0·422
	Mean	..	0·9619	0·5805	0·4291
	Mean	..	0·9558	0·5697	0·4081

It will be noticed that for the mature fibres the value of this ratio ranges from 0·930 to 0·975 among all the 22 cottons, the mean value being 0·9558 $\pm$ 0·00258. However, among the six immature cottons the range of the ratio is from 0·930 to 0·950 only, with a mean of 0·9417 $\pm$ 0·00350. Among the eight cottons of medium maturity the ratio ranges from 0·944 to 0·973 with a mean of 0·9602 $\pm$ 0·00459, while among the eight mature cottons it varies from 0·953 to 0·975 with a mean of 0·9619 $\pm$ 0·00383. If the differences between the mean values for the different groups are considered, it will be noticed that the value for the immature cottons (0·9417) is significantly less than that for the medium mature cottons (0·9602) and for the mature cottons (0·9619). The smaller value of the ratio for the immature cottons is due to the relatively lesser degree of secondary thickening even among the mature fibres in these cottons. That is, within the wide group that represents

the mature fibres relatively more of them lie nearer the lower border line of the ratio. Or in other words there is a shift in the maturity towards the lower limit of the maturity class. The possibility of such occurrence has been dealt with from *a priori* considerations by Peirce and Lord [1934,] also.

Coming to the half-mature fibres, the value of the ratio is found to range from 0·548 to 0·585 among all the 22 cottons the mean value being 0·5697 $\pm$ 0·00256. For the six immature cottons it varies from 0·550 to 0·562 with a mean of 0·5590 $\pm$ 0·00183, for the medium mature cottons from 0·548 to 0·578 with a mean of 0·5669 $\pm$0·00348, while for the mature cottons it ranges from 0·573 to 0·585 with a mean of 0·5805 $\pm$0·00208. The value for the mature cottons (0·5805) is significantly greater than that for the medium mature cottons (0·5669), and for immature cottons (0·5590).

Coming next to the immature fibres, the mean values of the ratio is found to range from 0·371 to 0·448, having a mean value of 0·408 $\pm$ 0·00509. For the immature cottons it varies from 0·371 to 0·406, with a mean of 0·3910 $\pm$ 0·00432, for the medium mature cottons from 0·374 to 0·427 with a mean of 0·3999 $\pm$ 0·00748 while for the mature cottons it ranges from 0·408 to 0·448 with a mean of 0·4291 $\pm$ 0·00591. The significances of the differences between the mean values for the different groups are the same as observed in the case of the half-mature fibres. The cause for the differences observed in the case of both half-mature fibres and immature fibres is the same as was stated in the case of the mature fibres, namely, the shift of the degree of maturity within a maturity class itself towards the lower limits of maturity in the less mature cottons.

The behaviour of the three foreign grown cottons may now be considered. It will be noticed that the values of the ratio for Sakels ‘ Saki ’ are nearly the same as for the other Indian cottons of similar fibre maturity, though the standard error (0·00297) of the mean value of the ratio for the immature fibres (0·443) is very much smaller than the values normally observed. In the other two cottons, A.R. Kampala and California, the value of the ratio for the half-mature fibres is nearly the same as for the other Indian cottons of similar fibre maturity but on the other hand the value for the mature fibres appears to be smaller and for the immature fibres greater than the corresponding values for similar Indian cottons. The consequences of this variation will be examined later.

(*c*) *Maturity coefficient.*—Using the mean values of the ratios obtained above the maturity coefficient could be calculated according to (1) which comes to

$$M_c = \frac{0{\cdot}9558M + 0{\cdot}5697H + 0{\cdot}4081\ I}{100} \tag{6}$$

But if, as already stated before, we have as our basis what we normally call a mature fibre then the coefficient could be calculated according to (2) which comes to

$$M_c = \frac{M + 0{\cdot}596H + 0{\cdot}427\ I}{100} \tag{7}$$

Before deciding on this equation as the final form we have to bear in mind the fact that the values of α, β and γ for the different groups of cottons are significantly different from one another in some cases. This gives the impression that the maturity coefficient calculated by using the individual mean values of the ratio obtained for each group of cotton would be a more accurate estimate. The three separate equations are as follows. For immature cottons

$$M_c = \frac{M+0{\cdot}594H+0{\cdot}415\,I}{100} \qquad (8)$$

for medium mature cottons

$$M_c = \frac{M+0{\cdot}590H+0{\cdot}416\,I}{100} \qquad (9)$$

and for mature cottons

$$M_c = \frac{M+0{\cdot}604H+0{\cdot}446\,I}{100} \qquad (10)$$

The values of the maturity coefficient calculated by using the separate equations for the different groups and also the single equation for all the groups along with the differences between the respective values are recorded in Table III.

It will be noticed that for immature and medium mature cottons the single equation gives a higher value than the separate equations for each of these groups, though, however, the differences are very small, the average value being 0·0078 for the former and 0·0048 for the latter cottons. On the other hand in the case of the mature cottons the single equation gives a lower value than the separate equations and the differences are even smaller in magnitude in this case, the mean value being only 0·0030. From the foregoing it is clear that the replacement of several equations by a single equation has produced negligible variation in the value of the maturity coefficient.

One other point requires to be considered. The constants for the single equation, 0·596 and 0·427, were obtained from the arithmetic means of the 22 values. But from what has already been stated the value of the constant is to some extent influenced by the fibre-maturity of the sample. Therefore, it would be more appropriate to take the weighed mean values. The weighing was done by using the values of the percentage of mature fibres for α, those of halfmature fibres for β and those of immature fibres for γ. Consequent on this the values of the constants were modified to 0·592 for half-mature fibres and 0·414 for immature fibres. It will be noticed from Table III that these values are subject to errors which make the third place not quite reliable. If, therefore, they are rounded up correct to the second place of decimals they become 0·59 and 0·41 respectively. As these

Table III

Values of the maturity coefficient obtained from different formulae

Serial number	Cotton	Separate equations (8), (9) and (10) A	Single equation (7) B	Difference A-B	Single equation (11) present formula C	Difference A-C	Equation (12) P and L's old formula D	Difference C-D	Equation (13) P and L's new formula E	Difference C-E	Derived from Equation (20) F	Difference C-F	Fibre weight per cm 10-6 gm.
1	3915F (Indore)	0·508	0·516	−0·008	0·499	+0·009	0·567	−0·068	0·335	+0·164	0·486	+0·013	1·00
2	LSS	0·536	0·545	−0·009	0·527	+0·009	0·586	−0·059	0·367	+0·160	0·516	+0·011	0·98
3	100F	0·544	0·552	−0·008	0·535	+0·009	0·591	−0·056	0·374	+0·161	0·524	+0·011	0·91
4	Sind Sudhar	0·552	0·560	−0·008	0·543	+0·009	0·600	−0·057	0·387	0·156	0·533	+0·010	0·92
5	4F	0·571	0·578	−0·007	0·564	+0·007	0·631	−0·067	·431	+0·133	0·556	+0·008	1·29
6	Perso American	0·589	0·596	−0·007	0·583	+0·006	0·645	−0·062	0·453	+0·130	0·575	+0·008	1·20
	Mean	..	..	−0·0078		+0·0082		−0·0615	·	+0·1507	..	+0·0101	..
7	47F	0·676	0·682	−0·006	0·672	+0·004	0·726	−0·054	0·576	+0·096	0·670	+0·002	1·39
8	3915 Q	0·694	0·699	−0·005	0·689	+0·005	0·738	−0·049	0·595	+0·094	0·688	+0·001	1·28
9	A. R. Kampala	0·741	0·746	0·005	0·740	+0·001	0·790	−0·050	0·672	+0·068	0·742	−0·002	1·62
10	Verum 262	0·754	0·758	−0·004	0·753	+0·001	0·805	−0·052	0·694	+0·059	0·756	−0·003	1·54
11	Kollpatti 1	0·746	0·751	−0·005	0·744	+0·002	0·788	−0·044	0·672	+0·072	0·746	−0·002	1·73
12	1027 A.L.F.	0·781	0·785	−0·004	0·781	+0·000	0·832	−0·051	0·735	+0·046	0·786	−0·005	2·46
13	California	0·784	0·789	−0·005	0·783	+0·001	0·826	−0·043	0·728	+0·055	0·787	−0·004	1·60
14	Jarila	0·785	0·789	−0·004	0·784	+0·001	0·828	−0·044	0·731	+0·053	0·789	−0·005	1·78
	Mean	..	..	−0·0048	..	+0·0019	..	−0·0484	·	+0·0679	..	−0·0022	..
15	Gadag 1	0·872	0·869	+0·003	0·867	+0·005	0·903	−0·036	0·845	+0·022	0·877	−0·010	1·68
16	Sake's 'Saki'	0·877	0·874	+0·003	0·872	+0·005	0·905	−0·033	0·849	+0·023	0·882	−0·010	1·27
17	Jayawant	0·888	0·885	+0·003	0·884	+0·004	0·914	−0·030	0·862	+0·022	0·894	−0·010	2·30
18	Hagari 1	0·887	0·884	+0·003	0·882	+0·005	0·912	−0·030	0·860	+0·022	0·893	−0·011	2·17
19	Nandyal 14	0·887	0·883	+0·004	0·881	+0·006	0·905	−0·024	0·852	+0·029	0·891	−0·010	2·01
20	Gaorani 12F	0·894	0·891	+0·003	0·888	+0·006	0·912	−0·024	0·862	+0·026	0·899	−0·011	2·25
21	Verum 434	0·904	0·901	+0·003	0·900	+0·004	0·923	−0·023	0·878	+0·022	0·911	−0·011	2·17
22	Mollisoni	0·933	0·931	+0·002	0·930	+0·003	0·948	−0·018	0·917	+0·013	0·943	−0·013	2·93
	Mean	..	..	+0·0030	·	+0·0048	..	−0·0272	..	+0·0224	..	−0·0108	..
	Mean	..	..	−0·0028	..	+0·0046	..	−0·0443	..	+0·0739	..	−0·0020	..

values do not differ much from 0·6 and 0·4 respectively and as the latter are more easy to remember they may be used instead, when equation (7) gets simplified to

$$M_c = \frac{M + 0{\cdot}6\ H + 0{\cdot}4\ I}{100} \tag{11}$$

It is now necessary to find out the error that is introduced by the simplification. This can be done by comparing the value of M_c obtained from (11) with those obtained from (8) (9) and (10)*. It will be noticed (Table III) that in all the 22 cottons except one, equation (11) gives a smaller value. The difference, however, is very small in magnitude ranging from 0·000 to 0·009 with a mean value of 0·0046, which means that the accuracy of the formula has not suffered by the simplification.

Yet another point requires consideration and that is regarding the inclusion of the three foreign cottons. This is specially necessary in view of the fact already mentioned, that two of these three cottons indicated somewhat different values of the ratios for the mature and immature fibres. Therefore, the constants were recalculated omitting these three cottons but the values obtained were found to be practically the same as those got previously, the differences produced being negligible. Hence it is not necessary to exclude the three foreign cottons from our analysis.

It should be remembered, however, that the constants derived above have been obtained indirectly from the volume and other dimensions of the fibre. A direct varification by actual weighing should be of considerable value. Such weighing was done by Peirce and Lord [1939, T. 186] and they used fibres swollen in caustic soda solution and separated into the three maturity classes. The difficulties involved in handling the very tiny bundles of slippery cm. long fibres swollen in the alkali, the removal of the alkali from them by washing are indeed great. Besides during these processes it is quite likely that some of the fibres may slip out and thus create errors. Therefore in the present work the fibres were weighed in the raw state after being separated into the mature, half-mature and immature classes by using the polarised light technique of Schwarz and others [1935 and 1938] already mentioned. After the examination of 22 cottons good experience had been gained for the proper allocation of the maturity class by that method. Fibres cut to cm. lengths were viewed individually under polarised light, the maturity class of each fibre was ascertained and the fibres falling within the mature, half-mature and immature classes were collected each in a separate pouch suitably designated. Two lots of 800 to 900 fibres each were examined for each sample and in that way four samples of cotton were tested, the testing of more samples being precluded by the strenuous nature of the work. The results obtained are given in Table IV.

*Equations (8), (9) and (10) have been derived from the arithmetic mean values of α, β and γ for each group of cottons and from the previous reasoning it would be more appropriate to use the weighed mean values in these cases also. When this modification was made it was found that no difference was observed in the value of Mc, upto the third place of decimals which is the last place taken in the present study, so far as equations (8) and (10) are concerned. However, in the case of equation (9) there was a difference of one unit in the third place in a few cottons only. Hence there would be little objection in using equations (8), (9) and (10) without modification for purposes of comparison.

TABLE IV

Ratio of the weight of a mature, half-mature and immature fibre to the weight of a mature fibre

Cotton	Mature	Half-mature	Immature
Perso American	1	0·65	0·41
47F	1	0·66	0·39
Verum 262 (1)	1	0·63	0·40
Verum 262 (2)	1	0·66	0·39
Mean	1	0·65	0·40

It will be noticed that in all the four samples of cotton the values of each ratio lie close to one another. The mean value* for the immature fibres, 0·40, coincides with that used in equation (11). However, the value for the half-mature fibres, 0·65, appears to be rather higher than the previous value 0·6. It should be noted that the former figure is derived from four samples of cotton only, while the latter one is derived from 22 samples of cotton. Furthermore by using 0·65 in place of 0·6 in equation (11) the value of the maturity coefficient is altered by a very small amount only. For these reasons equation (11) may be allowed to stand without any modification.

(*d*) *Comparison of the formulae.* The formula for the calculation of M_c obtained in the present work is

$$M_c = \frac{M + 0{\cdot}6H + 0{\cdot}4\,I}{100} \qquad (11)$$

The old formula of Peirce and Lord [1934] is

$$M_c = \frac{M + 0{\cdot}75H + 0{\cdot}45\,I}{100} \qquad (12)$$

†The new formula of Peirce and Lord (1939) is

$$M_c = \frac{1}{1{\cdot}2}\left\{\tfrac{1}{2}(M\text{-}I)/100 + 0{\cdot}7\right\} \qquad (13)$$

*The values recorded here have been obtained by correcting the weights of the mature, half-mature and immature fibres to those at 70 per cent R.H., pre-supposing that the moisture absorption capacity of each of the three types of fibres is the same. Whether it is so or if different whether it affects the values got here is dealt with in the appendix.

†In the paper by Peirce and Lord [1939] the quantity, maturity ratio (M_r) alone, has been considered. The maturity coefficient (M_c) can be derived from it in the following manner. If F is the fibre weight of a sample of cotton and if F_s and F_m are the values of F for standard (67-26-7) and complete (100-0-0) maturity respectively, then (continued on page 195, Footnote).

The values of M_c derived from the above three formulae are given in Table III. It will be noticed that the values got from the present formula (11) are in all cases intermediate between the values got from the other two formulae (12) and (13) being less than the former and more than the latter.

However, for the mature cottons the differences between the three sets of values are not considerable but these differences increase with the increase in the immaturity of the sample, being greatest for the very immature cottons. Furthermore, the divergence is more pronounced in the case of the new formula (13) of Peirce and Lord being as much as 0·16 in value for the very immature cottons.

The differences, noted above, lead to the question as to which of the three formulae is the most satisfactory one. This can be ascertained in the following manner. The average weight of cellulose per unit length of a fully mature fibre is given by $\frac{\Pi}{4} D^2 \rho M$, as was already pointed out before. It can also be obtained from the fibre weight corrected for moisture and other substances, namely, 0·9F, also previously considered. That is $0{\cdot}9F/M_c$ gives the weight of cellulose inside an average mature fibre and that inside a fully mature fibre is got by dividing this by α, (0·9558).

$$M_r = \frac{F}{F_s} \text{ and } M_c = \frac{F}{F_m} \qquad (14)$$

$$\text{Or } M_c = \frac{F_s}{F_m} M_r \qquad (15)$$

Now using the terms employed in the present work, equation (Ia) of Peirce and Lord (1939, T. 178) can be written as

$$M_r = \frac{F}{F_s} = \tfrac{1}{2}(M\text{-}I)/100 + 0{\cdot}7 \qquad (16)$$

If $M = 100$ and $I = 0$, then F F_m. Therefore from (16)

$$\frac{F_m}{F_s} = \tfrac{1}{2}(100\text{-}0)/100 + 0{\cdot}7 = 1{\cdot}2$$

$$\text{Or } \frac{F_s}{F_m} = \frac{1}{1{\cdot}2} \qquad (17)$$

From (15), (16) and (17)

$$M_c = \frac{1}{1{\cdot}2} \left\{ (\tfrac{1}{2}(M\text{-}I)/100 + 0{\cdot}7) \right\} \qquad (13)$$

Therefore we can write

$$\frac{\Pi}{4} D^2 \rho M = \frac{0{\cdot}9F}{M_c \times 0{\cdot}9558}$$

$$\text{Or } D = \sqrt{\left\{\frac{3{\cdot}6F}{0{\cdot}9558\ \Pi .\ \rho M\ M_c}\right\}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (18)$$

With the help of this equation the diameter could be predicted using the value of M_c got from (11), (12) and (13), and the predicted value in each case could be compared with the actual mean value of the diameter obtained microscopically. The closeness of the agreement is an indication of the efficiency of the particular formula. The results obtained are recorded in Table V.

It will be noticed that the difference (col. 6) between the actual value of the diameter and the value predicted by using the formula derived in the present investigation expressed as a percentage of the former, ranges from —3·3 to + 6·3 per cent, the mean difference for all the cottons taken together being + 0·66 ± 0·534, which is not significant. If the three groups are considered separately, it will be seen that the mean value for the mature cottons is +1·46 ±0·895 and for the medium mature cottons —0·30 +0·859, while for the immature cottons it is ± +0·87 +1·046, all the differences being non-significant. It follows, therefore, that the diameter predicated by using the present formula agrees closely with that obtained microscopically for all types of cottons. It will also be noted in Fig. 3 that the differences observed in this case lie on either side of zero and are independent of the immaturity of the sample.

Coming next to the difference (col. 8) between the value of the diameter predicted using the old formula of Peirce and Lord and the actual value, it is found to vary from –7·8 to+5·0 per cent, the mean difference for all cottons being —2·47** ±0·629, which is significant. For the mature group of cottons, however, the mean difference is + 0·05±0·900 which is not significant. On the other hand for the medium mature group it is —3·42** ±0·743 significant and for the immature group it is —4·55** ±0·864 also significant. Which means that except for the mature cottons, for which there is agreement in the other two groups of less mature cottons the diameter predicted by using the old formula of Peirce and Lord [1934] is significantly smaller though, however, the deficit is small and cannot be considered to be of much consequence if some error is tolerated, as can also be seen in Fig. 3.

Next if we consider the values predicted from the new formula of Peirce and Lord it will be noted that the difference (col. 10) is generally much larger, ranging from 0·0 to +27·8 per cent. All the differences excepting the one which is zero are positive indicating that the predicted value in this case is generally higher. The mean difference for all the 22 cottons is +7·92** ±1·645, which is significant. That for the mature group of cottons, +2·81* ±0·928, though small is significant, while for the medium mature group it is +4·80** ±1·194 also significant and for the immature group it is as large as 18·90** ±1·931 per cent, of course significant.

TABLE V

Values of fibre diameter (in μ) obtained microscopically and predicted by using M_c calculated by different formulae

Serial number	Cotton	Maturity per cent	Microscopical value	From fibre weight maturity coefficient							
				Equation (11) Present		Equation (12) P and L (Old)		Equation (13) P and L (New)		Modified P and L (New)	
				Value	Difference per cent	Value	Difference per cent	Value	Difference per cent	Value	Difference per cent
1	3915F (Indore)	9-22-69	20·5	21·5	+4·9	20·2	—1·5	26·2	+27·8	21·8	+6·3
2	LSS	16-17-67	20·8	20·7	—0·5	19·6	—5·8	24·8	+19·2	20·9	+0·5
3	100F	18-14-68	20·4	19·8	—2·9	18·8	—7·8	23·7	+16·2	20·0	—2·0
4	Sind Sudhar	19-16-65	19·6	19·8	+1·0	18·8	—4·1	23·4	+19·4	19·9	+1·5
5	4F	19-26-55	22·7	23·0	+1·3	21·7	—4·4	26·3	+15·9	23·1	+1·8
6	Perso American	23-23-54	21·5	21·8	+1·4	20·7	—3·7	24·7	+14·9	21·9	+1·9
	Mean		.		+0·87	.	—4·55**		+18·90**		+1·0
	S.E.			.	±1·046		±0·864		±1·931	.	±1·101
7	47F	38-23-39	21·6	21·8	+0·9	21·0	—2·8	23·6	+9·3	21·9	+1·4
8	3915Q	42-19-39	20·9	20·7	—1·0	20·0	—4·3	22·3	+6·7	20·7	—1·0
9	A. R. Kampala	48-25-27	21·6	22·5	+4·2	21·7	+0·5	23·6	+9·3	22·4	+3·7
10	Verum 262	50-27-23	21·6	21·7	+0·5	21·0	—2·8	22·6	+4·6	21·7	+0·5
11	Koilpatti 1	51-20-29	24·0	23·2	—3·3	22·5	—6·2	24·4	+1·7	23·1	—3·8
12	1027 A.L.F.	55-28-17	26·7	26·9	+0·7	26·1	—2·2	27·8	+4·1	26·9	+0·7
13	California	57-21-22	22·0	21·7	—1·4	21·1	—4·1	22·5	+2·3	21·6	—1·8
14	Jarila	57-22-21	23·6	22·9	—3·0	22·3	—5·5	23·7	+0·4	22·8	—3·4
	Mean	.		.	—0·30		—3·42**	.	+4·80**	.	—0·46
	S.E.	.		.	±0·859	.	±0·743		±1·194	..	±0·896

TABLE V—*contd.*

Values of fibre diameter (in μ) obtained microscopically and predicted by using M_c calculated by different formulae

Serial number	Cotton	Maturity per cent	Microscopical value	From fibre weight maturity coefficient: Equation (11) Present — value	Equation (11) Present — Difference per cent	Equation (12) and L (Old) — value	Equation (12) and L (Old) — Difference per cent	Equation (13) P and L (New) — value	Equation (13) P and L (New) — Difference per cent	Modified P and L (New) — value	Modified P and L (New) — Difference per cent
15	Gadag 1	71-21-8	21·0	21·1	+0·5	20·7	—1·4	21·4	+1·9	21·0	0·0
16	Sakels 'Sski	72-19-9	18·6	18·3	—1·6	18·0	—2·3	18·6	0·0	18·2	—2·2
17	Jayawant	75-17-8	23·8	24·5	+2·9	24·1	+1·3	24·8	+4·2	24·4	+2·5
18	Hagari 1	75-17-8	23·6	23·8	+0·8	23·4	—0·8	24·1	+2·1	23·7	+0·4
19	Nandyal 14	76-12-12	22·2	22·9	+3·2	22·6	+1·8	23·3	+5·0	22·8	+2·7
20	Gaorani 12	77-12-11	24·2	24·2	0·0	23·9	—1·2	24·5	+1·2	24·0	—0·8
21	Verum 434	79-13-8	22·2	23·6	+6·3	23·3	+5·0	23·9	+7·7	23·4	+5·4
22	Mollison	85-10-5	27·0	26·9	—0·4	26·7	—1·1	27·1	+0·4	26·8	—0·7
	Mean				+1·46		+0·05		+2·81*		+0·91
	S.E				±0·895		±0·900		±0·928		±0·868
	Mean				—0·66		—2·47*		+7·92**		+0·62
	S.E				±0·534		±0·629		±1·645		±0·551

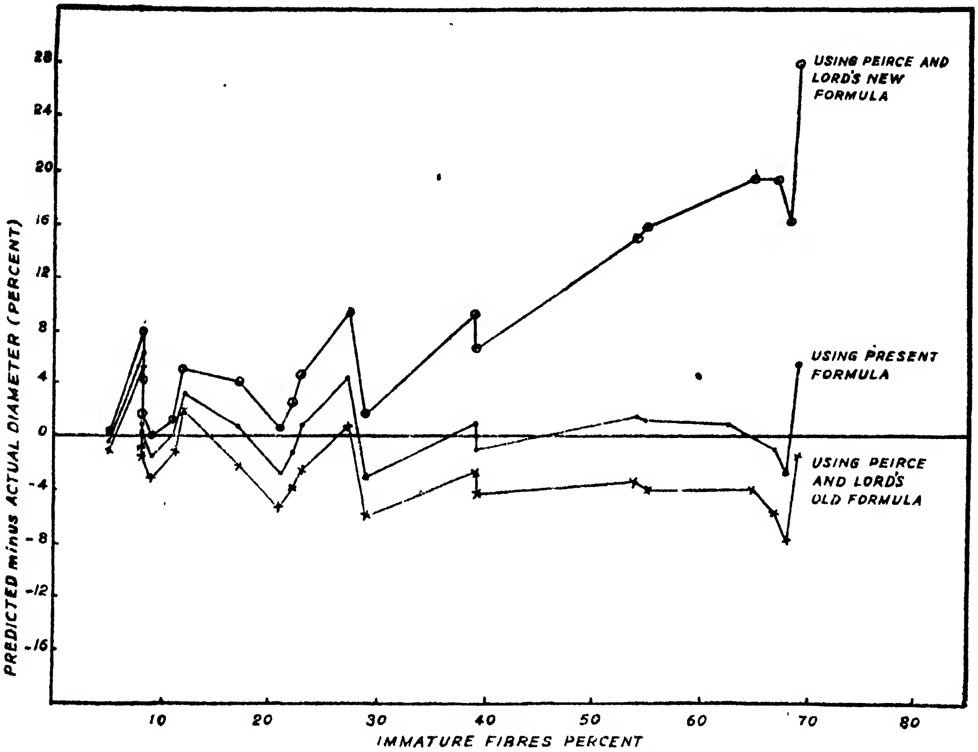


Fig. 3. Departure of the predicted value of the diameter, using the present formula the old and new formulas of Peirce and Lord, from its true value in relation to the fibre immaturity of the sample of cotton

It follows, therefore, that for the mature group of cottons the difference is small, for the medium mature group it is somewhat larger while for the immature group it is much larger indeed. There is a clear tendency for the difference to increase with the increase of immaturity of the sample, as can be seen in Fig. 3, unlike what was observed in the two previous cases.

From the foregoing it is clear that the present formula is quite satisfactory. The old formula of Peirce and Lord, though satisfactory for mature cottons appears to be somewhat defective for immature (Indian) cottons. Their new formula may be taken as valid for (Indian) cottons of good maturity but should be considered definitely erroneous for immature (Indian) cottons. It follows that while for the mature cottons all the three formulae appear to be satisfactory, for the immature cottons the new formula of Peirce and Lord should be considered definitely defective.

The cause of this defect may now be enquired into.

Rewriting (11) we have

$$100M_c = M + 0{\cdot}6H + 0{\cdot}4I \tag{11a}$$

Since $H = 100 - M - I$

$$\begin{aligned} 100M_c &= M + 60 - 0{\cdot}6M - 0{\cdot}6I + 0{\cdot}4I \\ &= 0{\cdot}4M - 0{\cdot}2I + 60 \\ &= 0{\cdot}4(M - \tfrac{1}{2}I) + 60 \end{aligned} \tag{19}$$

To get M_r we have to multiply M_c by F_m/F_s as already shown in the foot-note of p. 198. Using (11) and following the same procedure as done in the foot-note and assuming with Peirce and Lord [1939] the standard maturity to be 67-26-7, it can be easily shown that $F_m/F_s = 1{\cdot}171$. Therefore, multiplying both sides of (19) by 1·171 we have.

$$117{\cdot}1\ M_c = 100\ M_r = 0{\cdot}468\ (M - \tfrac{1}{2}\ I) + 70{\cdot}3$$

On approximately $100\ M_r = \frac{1}{2}(M - \frac{1}{2}\ I) + 70$

$$\text{Or } M_r = \frac{\frac{1}{2}(M - \frac{1}{2}\ I) + 70}{100} \tag{20}$$

which, surprisingly enough, is the same as the new formula of Peirce and Lord, except that I is replaced by $\frac{1}{2}$I, that is, a lower weighing is given for the immature fibres.

The validity of this formula could be verified, as was done before, by comparing the diameter predicted by using this formula with the actual value. This comparison is shown in the last two columns of Table V. It will be noticed that the mean difference for all the cottons taken together is $+0{\cdot}62 \pm 0{\cdot}551$, for the mature group of cottons $+0{\cdot}91 \pm 0{\cdot}868$, for the medium mature group $-0{\cdot}46 \pm 0{\cdot}896$ and for the immature group it is $1{\cdot}67 \pm 1{\cdot}101$. All the differences are found to be small and non-significant, which establishes the validity of the formula (20).

If we now compare the differences observed in the case of the new formula of Peirce and Lord (col. 10) with those obtained in the case of the above formula (col. 12), it will be noticed that the mean value for all the cottons which is +7·92** per cent for the former is as low as +0·62 per cent for the latter. For the mature group of cotton there is a similar though smaller reduction from +2·81* to +0·91 per cent and for the medium mature group a reduction from +4·80** to —0·46 per cent while for the immature group of cottons it is reduced from the large value of +18·9** per cent to the small value of +1·67 per cent. On the whole it appears that the values for the two sets of differences approach each other in the mature cottons but the divergence between them widens with the increase of immaturity. The difference between the two formulae (13) and (20) lies, as was already pointed out, in the weighing of I, which is lower in (20) and this lower weighing has remedied the defect observed in the case of (13). That the lower weighing of I is also the more appropriate one can be seen in equations (11) and (12) which have been derived from *a priori* considerations using the data experimentally obtained. It

is, therefore, clear that the higher weighing of I in (13) is responsible for the discrepancy observed. However, if the value of I is small as in mature cottons the error caused by this factor is not considerable, but when its value is large as in immature cottons the error becomes very much indeed as was found above.

One more point may be considered and that is the difference between the old formula of Peirce and Lord (12) and the present formula (11). Actually the difference is in the values of the coefficients of H and I which are 0·75 and 0·45 respectively in the former case while they are 0·6 and 0·4 respectively in the latter case. It was already pointed out that for two out of the three cottons grown in foreign countries the mean value of the ratio for mature fibres was lower while for the immature fibres it was higher than the values of the corresponding Indian cottons. Both these facts jointly tend to increase the value of the coefficients H and I. If, therefore, the above-mentioned tendency is a general feature for all cottons of foreign origin, it may partially explain the higher values found in (12). Besides this, the lines of demarkation of the border—land between the maturity classes, being subjective in nature, may not be the same in both the methods for finding the immaturity counts. Furthermore, the difficulty involved in handling the slippery fibres, which has already been dealt with, may also be a source of error in the former case. These foregoing points may offer an explanation for the difference between (11) and (12). However, as was already pointed out, this difference is small and the error introduced by using (12) in place of (11) is not of much consequence, if some error is tolerated for immature cottons.

(*c*) *Mature fibre weight.* Peirce and Lord [1934] have introduced a new expression called 'standard hair-weight', which is the fibre weight of a sample of *standard* maturity. This *standard* maturity, according to them, is the maturity of a 'normal sample of well-matured cotton' 'from general experience'. In 1934 they fixed the *standard* at 64-29-7, and later in 1939 changed the *standard* to 67-26-7, while at the same time they also stated that 'growers in a field where cotton does not normally attain to full maturity of secondary thickening may find it more convenient to correct hair-weights to a lower standard of maturity, say (N-D)=30 in., while in the previous case N-D was 60. From all this it is clear that the standard has no theoretical basis. It is purely emperical and has been changed from time to time. In the case of Indian cottons also no standard could be fixed for different types of cotton. Normally the degree of maturity for *hirsutum* cottons is entirely different from that for *herbaceum* and *arboreum* cottons. Furthermore the degree of maturity differs in different localities, as also noted by Peirce and Lord. Hence it is not correct to say that 67-26-7 or for that matter any other value of fibre maturity is the standard value for Indian cottons. When there is no standard there can be no standard fibre weight. In its place we should have a quantity that is free from arbitrariness. The weight of an average mature fibre of a sample of cotton satisfies this condition. There is no arbitrariness about it and it is independent of the maturity of the sample. It can be calculated by dividing the fibre weight by the maturity coefficient and can be called the '*mature fibre weight*'. The square root of this quantity multiplied by a constant, as shown in equation (18), gives

the mean diameter of the fibre which is a genetic character of a strain of cotton. On account of these reasons the expression '*mature fibre weight*' is recommended for general use in place of standard fibre weight.

Summary

Maturity coefficient of a cotton is a unitary expression to signify the multiple character of fibre maturity, usually represented by the percentage of mature, half-mature and immature fibres. In order to calculate the Maturity Coefficient for Indian cottons, constants have been obtained in the present study employing a new method. For each fibre swollen in 18 per cent caustic soda solution the maturity class, the fibre diameter, D, and the lumen diameter, d, were determined. From the mean value of the expression, $\frac{D^2-d^2}{D^2}$, for the fibres falling within each maturity class and the mean fibre weight of the sample the constant for each class was derived. By studying 22 cottons covering a wide range of fibre maturity it was found that the Maturity Coefficient, M_c, is given by

$$M_c = \frac{M + 0{\cdot}6H + 0{\cdot}4I}{100},$$ where M, H and I represent the percentages of the mature, half-mature and immature fibres respectively in the sample. The validity of this formula was directly verified by actually weighing cm. long raw cotton fibres separated out into the three maturity classes using the polarised light technique. The present formula, however, is somewhat different from both the old and the new formulae given by Peirce and Lord and the question arises as to which of the three is the most suitable for Indian cottons. This point was clarified by comparing the value of the diameter predicted by using the M_c calculated according to a particular formula with the value actually obtained by means of the microscope. It was found that the present formula was quite satisfactory. The old formula of Peirce and Lord was also fairly satisfactory if some error was tolerated for immature cottons. Their new formula, however has been found to be definitely unsuitable for immature cottons. The cause of this defect has been analysed and it has been shown that this formula, if modified a little, would serve very satisfactorily. It has also been suggested that the expression 'mature fibre weight is to be used in preference to standard fibre weight' as the former is free from any arbitrariness of the standard.

Appendix

Hygroscopicity of normal mature lint and of immature lint from 20-day old bolls of 4F Cotton

As pointed out previously the object of the study is to find out whether the moisture absorption capacity of immature fibres is the same as that of the normally mature fibres. For this purpose it is necessary to separate out the immature fibres present in a normal sample of lint. But this is not a practical proposition. Hence

completely immature fibres were obtained from 20-day old bolls. The bolls were out open and the locks were separated and washed gently in water to remove the mucilagenous and sticky matter. The seeds were separated from one another and the fibres removed from them were dried at about 35°C. These fibres when examined under the microscope were found to possess no secondary thickening at all. The sample of normal lint from fully opened bolls was obtained later on from the same 4F plants from which the 20-day old bolls were taken.

The samples of immature lint and normal lint were next tested for their hygroscopicity. Duplicate samples of each type of lint, put in weighing bottles, were placed inside a desiccator containing sulphuric acid solution of the required strength to give a R. H. of 20 per cent, inside the chamber. Repeated weighings were made over a number of days until constant weights were noted, when the solution was diluted to give 30 per cent R. H. The lint samples were again placed inside the chamber and weighings were made until constant weights were attained. The solution was next diluted to give 40, then 50, 60, 70 and 80 per cent, R.H. and the process was repeated as before. It could not be continued to further higher humidities because fungus was formed on the immature samples of lint at 80 per cent R.H. The samples were then dried at 110°C. until constant weight was attained and from this weight the moisture regain was calculated. The results obtained are given in Table VI.

TABLE VI

Moisture regain (per cent) at various relative humidities of normal and immature 4F lint

R.H. per cent	Normal lint			Immature lint		
	I Test	II Test	Mean	I Test	II Test	Mean
Dry	0	0	0	0	0	0
20	2·79	2·75	2·77	11·97	13·08	12·52
30	3·97	3·90	3·94	14·04	15·22	14·63
40	4·76	4·66	4·71	15·77	17·08	16·42
50	5·77	5·69	5·73	18·35	19·91	19·13
60	6·35	6·33	6·34	20·23	21·87	21·05
70	7·98	7·97	7·98	25·50	24·58	25·04
80	10·23	10·23	10·23	27·31	26·12	26·72

It will be noticed that the duplicate tests agree closely for both kinds of lint and particularly so in the case of the normal lint. The values of the regain for normal lint are in conformity with those obtained by Urquhart and Williams [1924 and 1926], if it is remembered that the experimental conditions in the present work were not sensitive enough to detect hysteresis. On the other hand the regain values

for the immature lint are very much higher than the corresponding values for normal lint, being as high as 12·5 per cent even at 20 per cent R.H. The rate of increase of regain with R.H. is also considerably higher for the immature lint as can be seen in fig. 4.

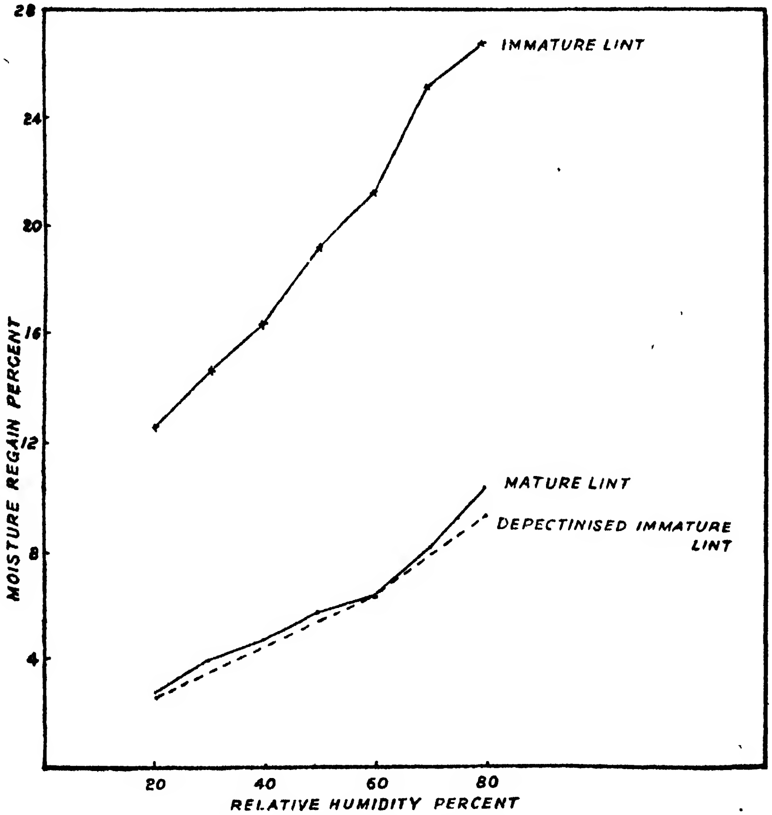


FIG. 4. Moisture regain values at different relative humidities for normal mature lint and for immature lint and depectinized immature lint

In order to find out the cause for the difference observed above and in order to see whether sterilizing the sample would overcome the fungus development, the following procedure was adopted. The four samples were each further sub-divided into two nearly equal parts. Thus eight samples, four of normal lint and four of immature lint were obtained and their dry weights were determined. Two of these samples of each type of lint were sterilized in two per cent formalin solution with a little alcohol and the remaining two samples were depectinized by the following process. Each sample was boiled for four hours in one per cent caustic soda solution, being all the while kept under a porcelain dish with perforations so that it

did not come in contact with air. The sample was then washed, soured in half per cent acetic acid and then washed over and over again until all the acid was removed. The water was squeezed out and the sample was allowed to dry in air. It was next dried in the oven at 105°C. and the dry weight was determined from which the loss sustained by the depectinization or sterilization process was obtained. The results are given in Table VII.

TABLE VII

Loss (per cent) due to depectinization or sterilization of normal and immature lint

	Description of sample	I Test	II Test	Mean
Nominal lint	Sterilized	2·4	2·4	2·4
do.	Depectinzed	7·8	7·2	7·5
Immature lint	Sterilized	23·2	21·5	22·4
do.	Depectinized	53·6	54·4	54·0

It will be noticed that in the case of the normal lint the loss due to sterilization with formalin is 2·4 per cent, while that due to depectinization is about 7·5 per cent. On the other hand in the case of immature lint the sterilization process has removed as much as about 22·4 per cent while depectinization has removed a still greater amount of about 54·0 per cent. This means that the immature lint sample from 20-day old bolls contains a large quantity of material which is soluble in alcohol, formalin solution and boiling sodium hydroxide solution. This material probably may be the residue of the boll fluid filling the cavity of the 20-day old fibre.

The eight samples considered above were then conditioned at 20, 60 and 80 per cent R.H. respectively in the same manner as was done earlier and from the dry weight the moisture regain for each R.H. was calculated. The results obtained are given in Table VIII.

TABLE VIII

Moisture regain (per cent) at various relative humidities of normal and immature (sterilized and depectinized) 4F lint

R.H. per cent	Normal lint						Immature lint					
	Depectinized			Sterilized			Depectinized			Sterilized		
	I	II	Mean	I	II	Mean	I	II	Mean	I	II	Mean
20	2·28	2·32	2·30	2·42	2·46	2·44	2·48	2·50	2·49	2·79	2·92	2·86
60	5·73	5·62	5·68	6·03	6·00	6·02	6·32	6·28	6·30	8·18	8·40	8·29
80	8·44	8·32	8·38	9·12	8·77	8·94	9·40	9·35	9·38	13·13	13·18	13·16

It will be observed that the moisture regain of immature lint samples has been reduced considerably by depectinization. It has been brought down practically to the same level as that shown by normal lint. Even washing with formalin solution has been able to effect a considerable change. What were originally about

13, 21 and 27 per cent respectively for 20, 60 and 80 per cent R.H. have been reduced to 3, 8 and 13 per cent respectively. Which means that the conspicous hygroscopicity of 20-day old lint is due to the presence of material which is removable to a large extent even by washing with formalin solution. What these substances are and how they are present in the fibres require to be determined but they are not pertinent to the present enquiry.

Incidentally it will be noted that the values recorded in Table VIII for depectinized lint, viz., 2·30, 5·66 and 8·38 are somewhat smaller than the corresponding values recorded in Table VI for normal lint, viz., 2·75, 6·33 and 10·23. Apart from depectinization causes, the differences observed are due to the fact that the former figures were obtained for samples of lint dried in the oven a number of times, where as the latter figures were obtained for raw lint samples.

From the above it is clear that completely immature fibres taken from 20-day old bolls show hygroscopic properties different from those of normal lint, which may be due to the presence of the residue of the boll fluid in the former case. But in a boll that opens normally there is no such fluid and therefore there is no chance of the presence of such residue inside the immature fibres that are found in normal lint. Moreover these immature fibres are not completely devoid of secondary thickening as 20-day old fibres are. Hence it can be expected that the difference in hygrospicity of the immature lint normally found in a sample of lint and that of the mature lint is not as large as was found above. Further detailed study is necessary to determine the extent of the differences. For such an enquiry the difficulties involved in the separation of the immature fibres from the normal lint has already been pointed out. A new method of obtaining the immature sample of lint or a different method of approach is called for. However, whatever may be the value of the difference in the hygroscopicities of the immature and mature lint it is hoped that it does not affect the values of the constants derived in the present study, as indirect verification has pronounced a satisfactory verdict.

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STUDIES ON THE PHYSIOLOGY OF GROWTH AND DEVELOPMENT OF *mung** (*phaseolus aureus Roxb.*)

(*a*) EFFECT OF THE TIME OF SOWING, (*b*) VERNALIZATION AND PHOTOPERIODISM

By J. C. Sen Gupta and D. K. Mukherji**, Presidency College, Calcutta

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(With Plates II, III and IV and twentytwo text—figures.)

NO work has been done on the fundamental aspects of the physiology of growth and development of the plant of *Mung* (*Phaseolus aureus Roxb.*) with reference to various external factors.

Any investigation on the physiology of nutrition or on the breeding, or on disease resistance, should be based on the optimum time for sowing the plant and for these studies it is extremely important to know the relative influence of the climatic factors on the growth and development of the plant.

To understand the nature of the responses of the plant to the different climatic factors, this investigation on the effect of different times of sowing on the growth and development of the plant was undertaken. In addition, the effect of pre-sowing low-temperature treatment of seeds, well known as vernalization, and the effect of daily light period known as photoperiodism respectively, were also investigated.

Experimental procedure

Two strains of *Mung* (1) I.P. 28 (seeds obtained through the courtesy of the Imperial Agricultural Research Institute), and (2) *Sona Mung* (the recommended variety for Bengal, seeds obtained through the courtesy of the Department of Agriculture, Government of Bengal) have been used in this investigation. Seeds, selected to be of uniform size as far as possible, were sown in earthen pots of 13 in. height and 14 in. diameter at the top in ordinary garden soil without the addition of any manure at the experimental pot culture garden of the Presidency College, Calcutta.

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* This plant commonly known in India as *Mung, Green gram, Golden gram, Sona Mung,* etc., has been long known botanically as *Phaseolus radiatus Auct.* non Linn. Piper and Morse in their interesting paper on 'Five oriental species of Beans'—U.S. Dept. of *Agriculture Bull.* No. **119** (1914) have pointed out that Linnaeus's type specimen of *Phaseolu radiatus* represents a plant which is not that of our common *Mung*. Therefore, the name *Phaseolus radiatus* Linn. can not be applied to that plant. The next available name, i.e., *Phaseolus aureus* Roxb. has therefore been accepted as the valid name by Piper and Morse for this plant. We are grateful to Dr Chatterjee, Systematic Botanist, Indian Agricultural Institute, New Delhi, for drawing our attention to Piper and Morses paper.

** At present, Research Fellow, National Institute of Sciences of India, C/o. Division of Botany, Indian Agricultural Research Institute, New Delhi.

For each pot, twelve seeds were sown in the afternoon, and when the seedlings appeared, four plants were kept equidistant from each other as far as practicable. Five pots were used for each treatment all the pots having the same type of soil. They were watered regularly and uniformly in the afternoon except on rainy days.

There were six sowings at an interval of 15 days commencing from 15 August 1945, *viz.*, 15 August, 30 August, 14 September, 29 September, 14 October, 29 October, and six additional sowings for *Mung* I.P. 28 at an interval of 30 days from 26 October 1944, viz., 26 October, 25 November, 25 December, 24 January (1945), 23 February and 25 March.

Photoperiodism

Sown on 14 September, 1945, one set of 20 plants was exposed to a short photoperiod of 10 hours, and a second similar set to a long photoperiod of 14 hours per day. In short photoperiod treatment the pots were taken to a ventilated dark room in the afternoon and kept till dusk, after which they were brought back to the open field. The hours of darkness necessary to complete 10 hours of daily light period were adjusted and the pots taken to the dark room at the desired time. The additional period of light for the long photoperiod was given in a ventilated room by exposing the plants to an electric light from 200 C.P. from a distance of one metre beginning from dusk, the period being suitably adjusted to make the daily light exposure period 14 hours.

Vernalization

Sown on the 14 September 1945.

For each variety, seeds, were exposed to a temperature varying from 2°C. to 4°C. in a refrigerator for a period of 10 days before sowing. 100 seeds of almost uniform size, for each variety, were soaked in water for 5 hours. It was found in a preliminary experiment that the time taken for the seed coat to burst, when soaked in water, was 5 hours 45 minutes.

Seeds were kept in the refrigerator at a temperature of 2°C. to 4°C. during the period of treatment from 4 September to the 14 September when they were sown in pots, five pots with twenty plants being used for this treatment as usual.

An experiment with 45 days of treatment of the seeds in a similar manner in September-October, showed that these seeds failed to germinate.

Developmental changes of the vegetative phase of the plants were followed by taking the following readings at intervals of 15 days.

Height. This was measured by centimetre scale from the level of the soil to the tip of the stem.

Number of nodes. All nodes including the cotyledonary node and excluding the undifferentiated nodes at the tip of the axis, were counted.

Number of leaves. All the leaves which unfolded their leaf-lamina were counted including the leaves produced on the branches, but excluding the cotyledonary leaves.

Number of branches. Number of branches from the main axis with at least one leaf, was counted.

The changes of the reproductive phase were followed by noting the following individually for each plant.

Budding. The date of the initiation of the first visible flower bud.

Flowering. The date of the opening of the first flower.

Fruiting. The date of the initiation of the first fruit.

The reading in each case was taken separately for each of the 20 plants for each treatment and the results recorded as mean of the 20 plants. In a few cases, *viz.*, the 25 December 1944, 24 January 1945, and 25 March 1945, sowings of I.P. 28, due to the premature death of some of the plants, it was not possible to have the mean readings for 20 plants especially in the records during the reproductive phase. In these cases the mean records of the different characters studied were for those plants which were living at that time without taking into consideration the dead ones.

Experimental results

Germination. The time—in days—taken for the germination of the seeds of the two varieties are given below :

Dates of sowing		26 October 1944	25 November 1944	25 December 1944	24 January 1945	23 February 1945	25 March 1945	15 August 1945	30 August 1945	14 September 1945	29 September 1945	14 October 1945	29 October 1945
Variety	I.P. 28	3	9	6	7	5	7	2	2	3	3	3	4
	Sona Mung	..	..	..	..	..	..	2	2	3	3	3	4

It is seen that germination is delayed during the colder months, and between August and October there is a general agreement between the two varieties in their times of germination.

Time of sowing. The total heights reached, the number of nodes, leaves, and branches at the fruiting stage, and the times of the initiation of the flower buds, opening of flower and the initiation of fruits are tabulated in the Table IA for I.P. 28, and IB for *Sona Mung* and represented graphically in Figs IA and Ia for I.P. 28, and IB and Ib for *Sona Mung*.

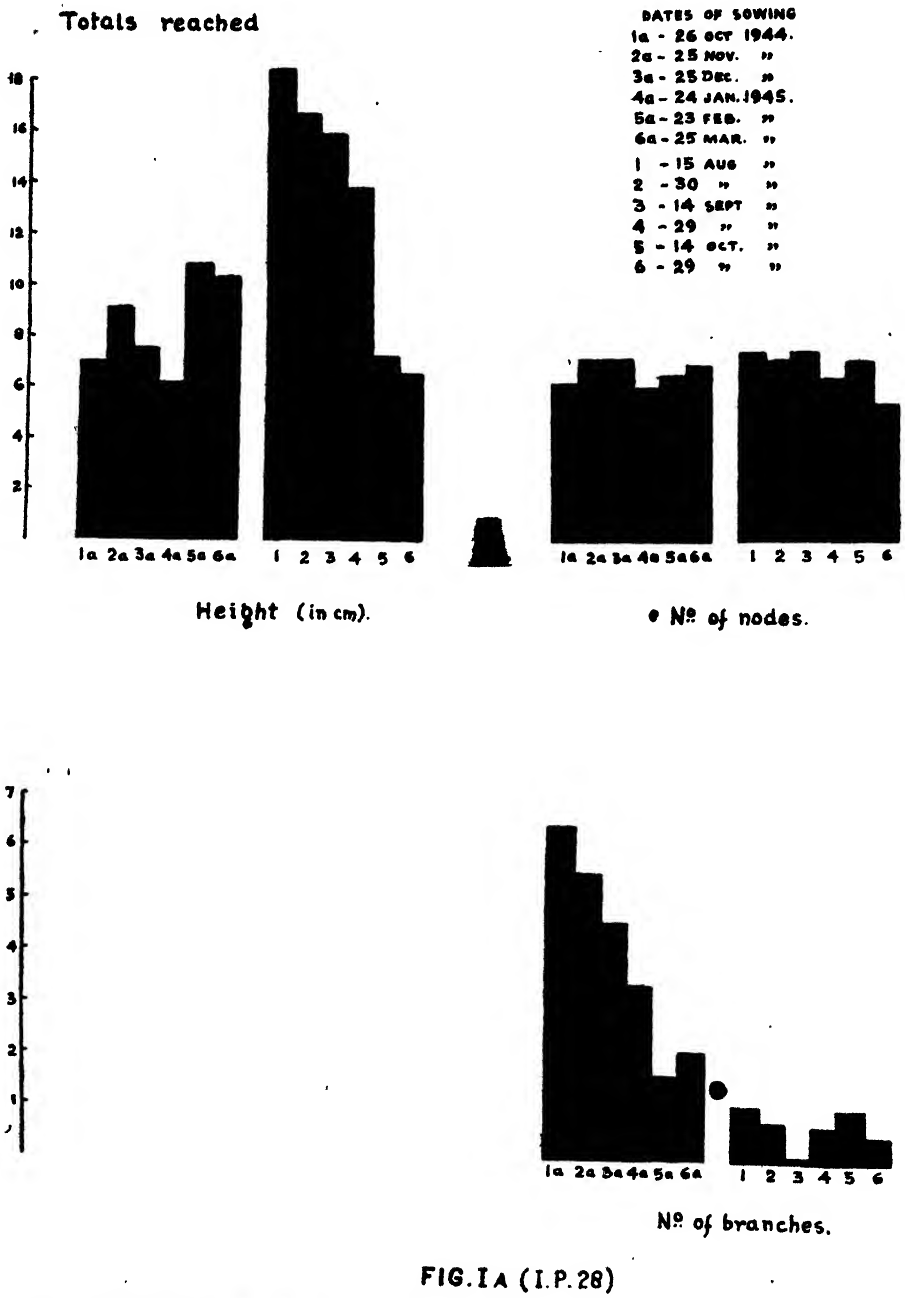


FIG. 1 A. Graphical representation of total heights, number of nodes, and number of branches

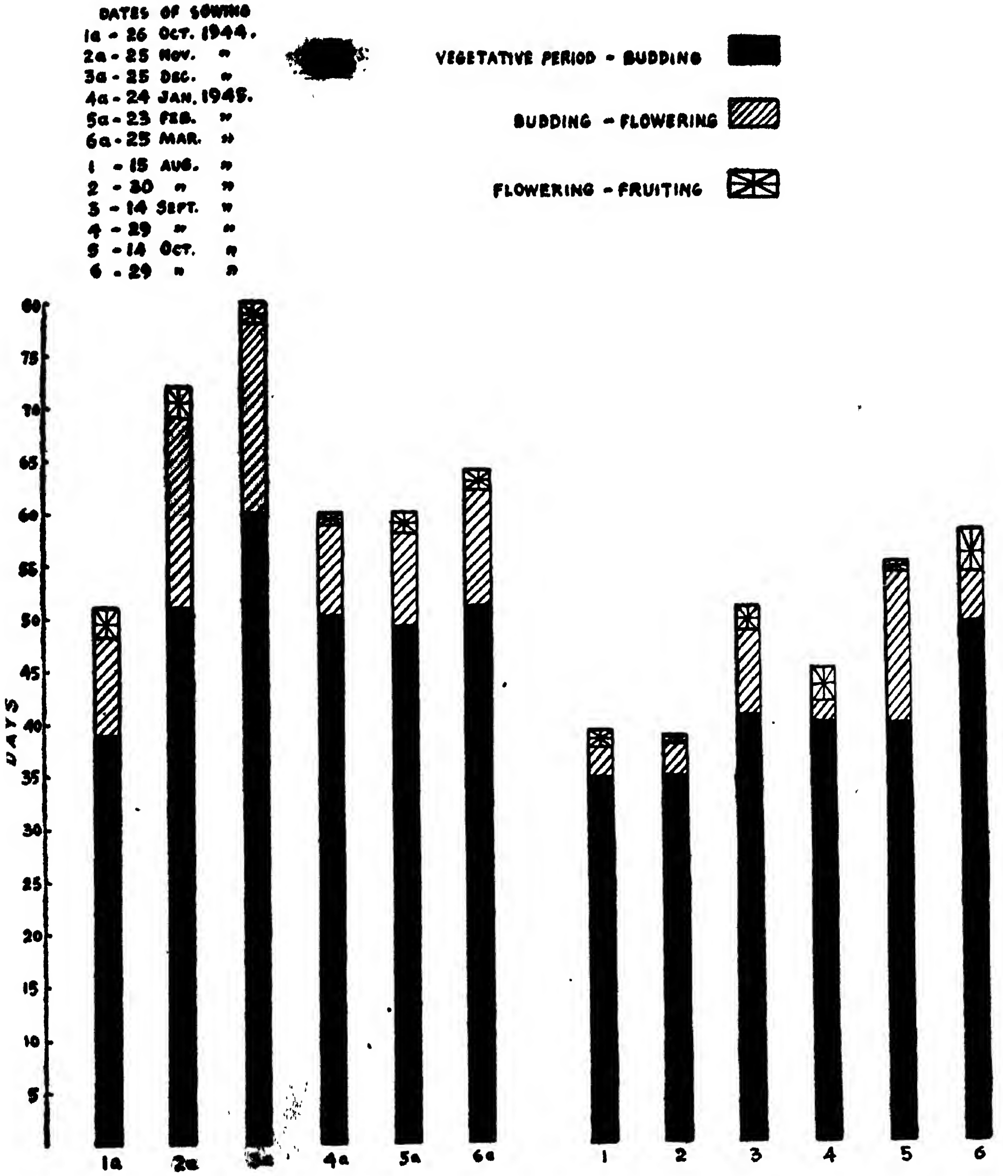


FIG. Ia. (I.P.28)

FIG. 1 A. Graphical representation of budding, flowering and fruiting

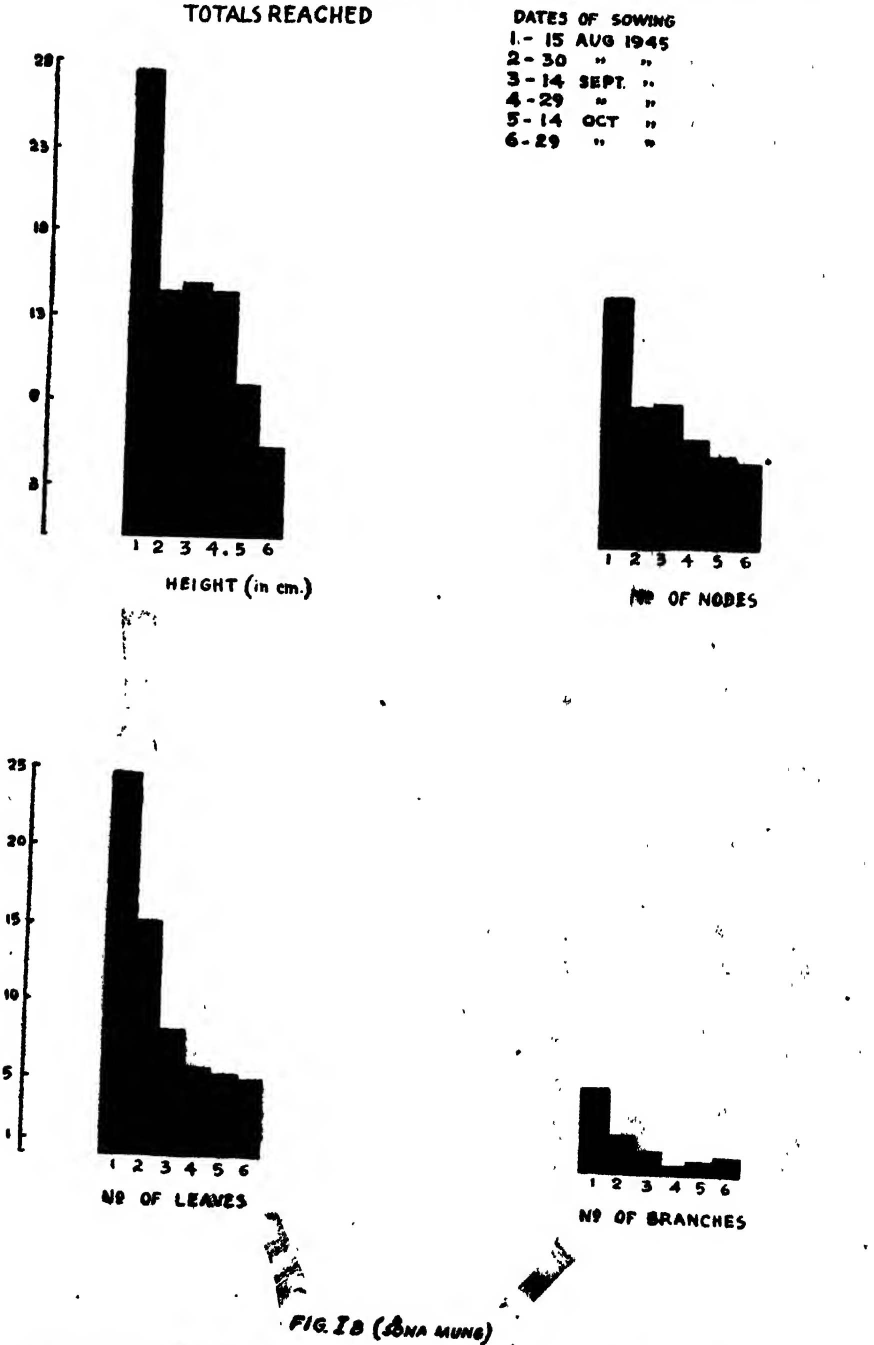


FIG. I B. Graphical representation of total heights, number of nodes, leaves and branches

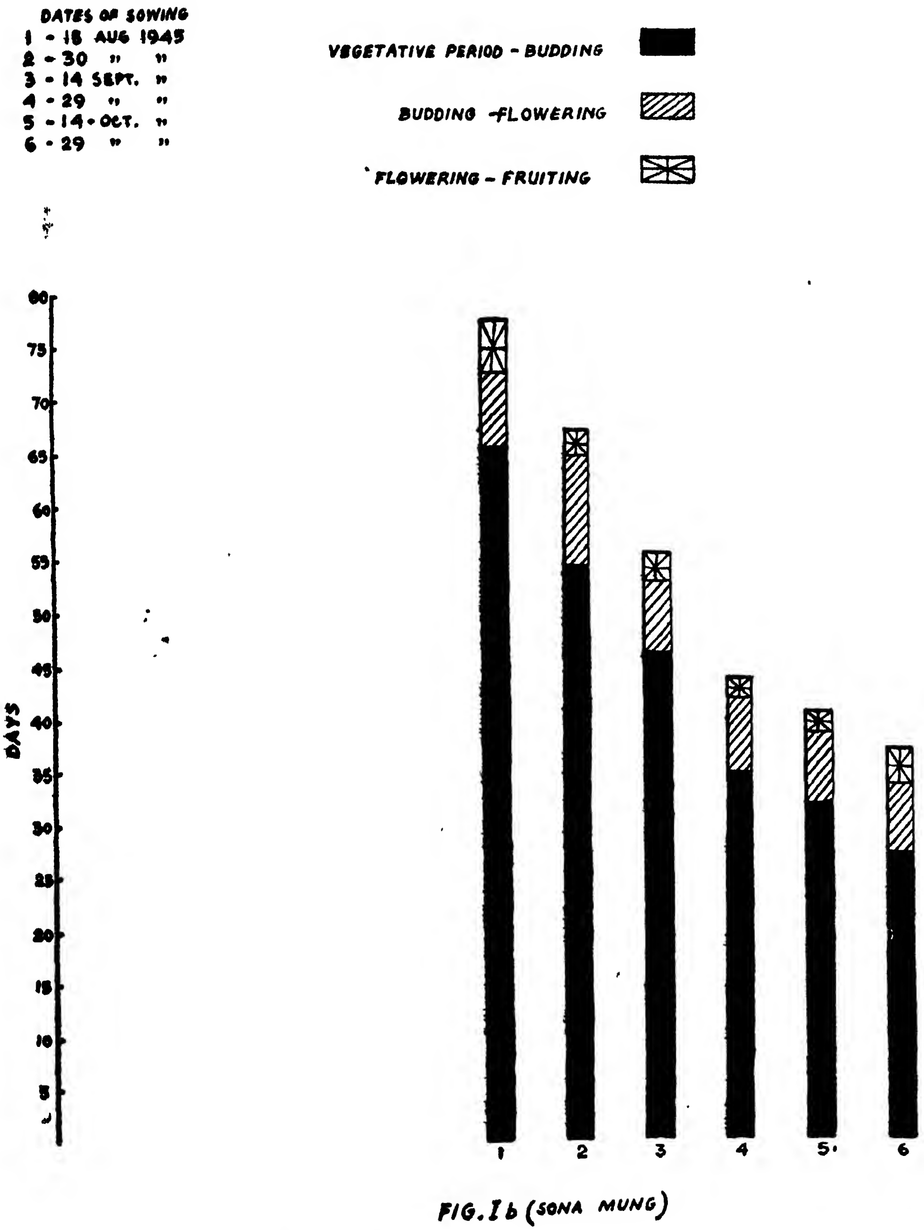


FIG. I B. Graphical representation of budding, flowering and fruiting

Table I

Budding, flowering and fruiting in days and their dates and total height, number of nodes, number of leaves and number of branches reached at the fruiting stage

Table I-A

(Mung IP-28)

Dates of sowing	Totals reached				Dates of			Days after sowing			Difference in days between	
	Height	Number of nodes	Number of leaves	Number of branches	Budding	Flowering	Fruiting	Budding	Flowering	Fruiting	Budding and flowering	Flowering and fruiting
26 October 1944	6·88	6·21	3·00*	6·47	4 December	13 December	16 December	39	48	51	9	3
25 November 1944	9·11	7·21	5·73*	5·53	15 January	2 February	5 February	51	69	72	18	3
25 December 1944	7·54	7·20	3·00*	4·60	23 February	13 March	15 March	60	78	80	18	2
24 January 1945	6·15	6·00	6·60	3·40	15 March	24 March	25 March	50	59	60	9	1
23 February 1945	10·60	6·50	7·89	1·61	13 April	22 April	24 April	49	58	60	9	2
25 March 1945	10·22	6·88	9·77	2·11	15 May	26 May	28 May	51	62	64	11	1
15 August 1945	18·35	7·33	7·25	1·05	19 September	22 September	23 September	34·80	37·57	39·32	2·77	1·75
30 August 1945	16·66	7·10	6·15	0·73	4 October	7 October	8 October	35·11	37·95	38·55	2·84	0·60

14 September 1945	15·87	7·37	3·84*	0·05	24 October	2 November	4 November	40·45	48·55	50·72	8·10	2·17
29 September 1945	13·81	6·37	4·37	0 66	8 November	10 November	13 November	39·70	41·75	45·00	2·05	3·25
14 October 1945	7·19	7·10	6·55	0·95	23 November	7 December	8 December	39·82	54·50	55·00	14·68	0·50
29 October 1945	6·47	5·42	6·26	0·42	17 December	22 December	26 December	49·41	54·00	58·00	4·59	4·00

TABLE I-B

(Sona Mung)

15 August 1945	27·25	14·61	24·72	5·50	20 October	27 October	1 November	65·50	72·80	77·70	7·30	4·90
30 August 1945	14·36	8·15	15·20	2·55	23 October	2 November	4 November	54·35	64·68	67·21	10·33	2·53
14 September 1945	14·53	8·40	8·20	1·55	30 October	6 November	9 November	46·10	52·84	55·47	6·74	2·63
29 September 1945	14·35	6·30	5·85	0·56	3 November	10 November	12 November	34·85	41·77	43·87	6·92	2·10
14 October 1945	8·98	5·25	5·35	0·95	15 November	22 November	24 November	31·60	38·63	40·55	7·03	1·92
29 October 1945	5·28	5·00	5·10	1·25	25 November	2 December	5 December	27·00	34·22	37·00	7·22	2·78

* The total number of leaves decreased at the final observation as many of them were shed before fruiting.

F

In the following tables the growth in height, the number of nodes, leaves and branches are given for every 15 days. [It should be noted that the measurements for the vegetative growth were discontinued after fruiting, the period up to which the readings were taken.]

The heights reached and the increase in height for every 15 days, and the average rate of increase in height per day calculated by dividing the total height reached by the time taken to attain it, are tabulated in Tables IIA and IIB and the data are graphically represented in Figs. IIA and IIB for I P-28 and *Sona Mung* respectively.

Table II-A

(*Mung IP-28*)

Dates of sowing	Days after sowing—height						Increment in heights between					Average rate of increase per day
	15	30	45	60	75	90	15 to 30th day	30 to 45th day	45 to 60th day	60 to 75th day	75 to 90th day	
26 October 1944	3·53	4·73	6·13	6·88	..	..	1·20	1·40	0·75	..	..	0·11
25 November 1944	2·35	2·74	3·80	6·58	9·11	..	0·39	1·06	2·78	2·53	..	0·12
25 December 1944	1·58	2·41	2·75	3·31	4·50	7·54	0·83	0·34	0·56	1·19	3·04	0·08
24 January 1945	1·47	2·42	3·04	6·15	..	.	0·95	0·62	3·11	..	.	0·10
23 February 1945	2·59	4·23	8·67	10·69	.	.	1·64	4·44	2·02	..	..	0·18
25 March 1945	1·53	3·96	5·23	10·22	..		2·43	1·27	4·99	..	.	0·17
15 August 1945	10·85	17·75	18·35	..	..	..	6·90	0·60	..	..	..	0·41
30 August 1945	8·62	15·11	16·66	..	..	.	6·49	1·55	..	..	..	0·37

Table II-A *contd.*

(*Mung IP-28*)

Dates of sowing	Days after sowing—after						Increment in height between					Average rate of increase per day
	15	30	45	60	75	90	15 to 30th day	30 to 45th day	45 to 60th day	60 to 75th day	75 to 90th day	
14 September 1945	5·83	12.26	14·95	15·87	.	..	6·43	2.69	0·92	..	..	0·26
29 September 1945	5·36	11·75	13·81	..			6·39	2·06		..	.	0·31
14 October 1945	5·13	6·21	7·11	7·19			1·08	0·90	0·08	..		0·12
29 October	3·98	4·74	6·16	6·47			0·76	1·42	0·31	..	..	0·11

Table II-B

(*Sona Mung*)

Dates of sowing	Days after sowing—after						Increment in height between					Average rate of increase per day
	15	30	45	60	75	90	15 to 30th day	30 to 45th day	45 to 60th day	60 to 75th day	75 to 90th day	
15 August 1945	7·45	11·98	23·93	26·26	27·25	..	4·53	11·95	2·33	0·09	..	0·8
30 August 1945	7·10	12·00	12·75	13·10	14·36	..	4·90	0·75	0·35	1·26	..	0·19
14 September 1945	6·85	12·93	13·28	14·53			6·08	0·35	1·25	..	.	0·24
29 September 1945	6·63	12·23	14·35			.	5·60	2·12		.	..	0·32
14 October 1945	6·53	7·57	8·98	..		.	1·04	1·41		..	..	0·20
29 October 1945	3·50	5·10	5·28	..		.	1·60	0·18	1·26		.	0·12

The number of nodes, the increase in the number every 15 days, and the average daily increase in the number of nodes are tabulated in Tables IIIA and IIIB, and represented graphically in Figs. IIIA and IIIB for IP-28 and *Sona Mung* respectively.

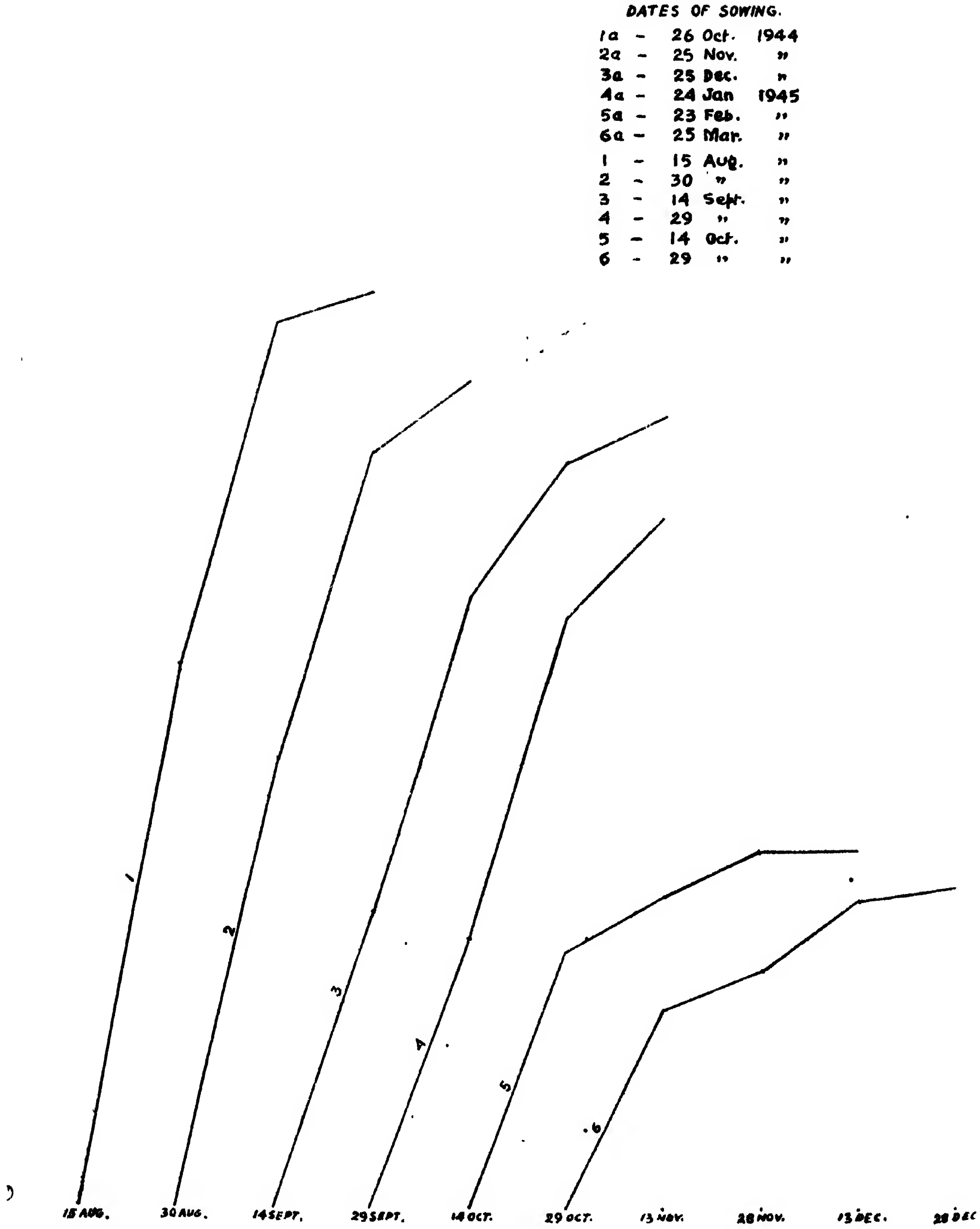
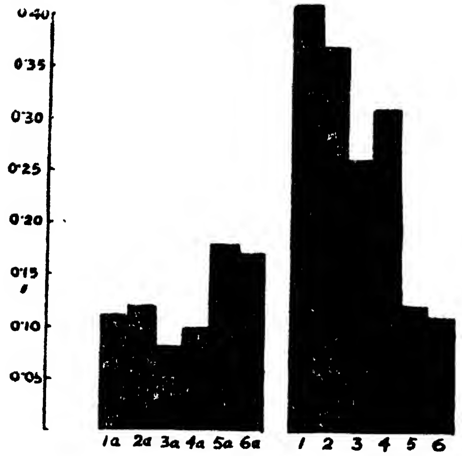


FIG II A

IIA. (I. P-28). Graphical representation of the number of nodes, increase in number after every 15 days, and average daily increase in the number of nodes.



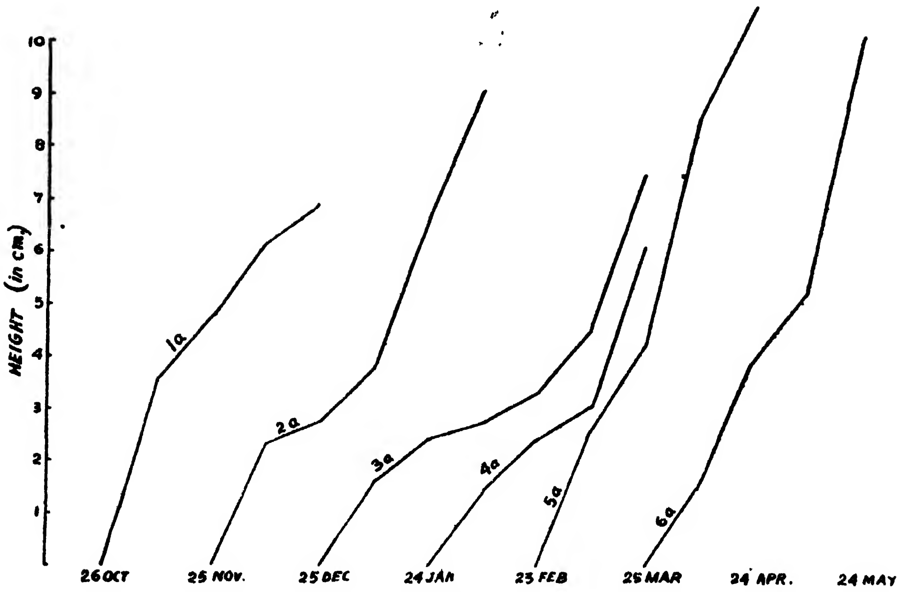


FIG IIA (I. P. 28)

FIG. 11A. Graphical representation of the number of nodes, increase in number after every 15 days and average daily increase in the number of nodes.

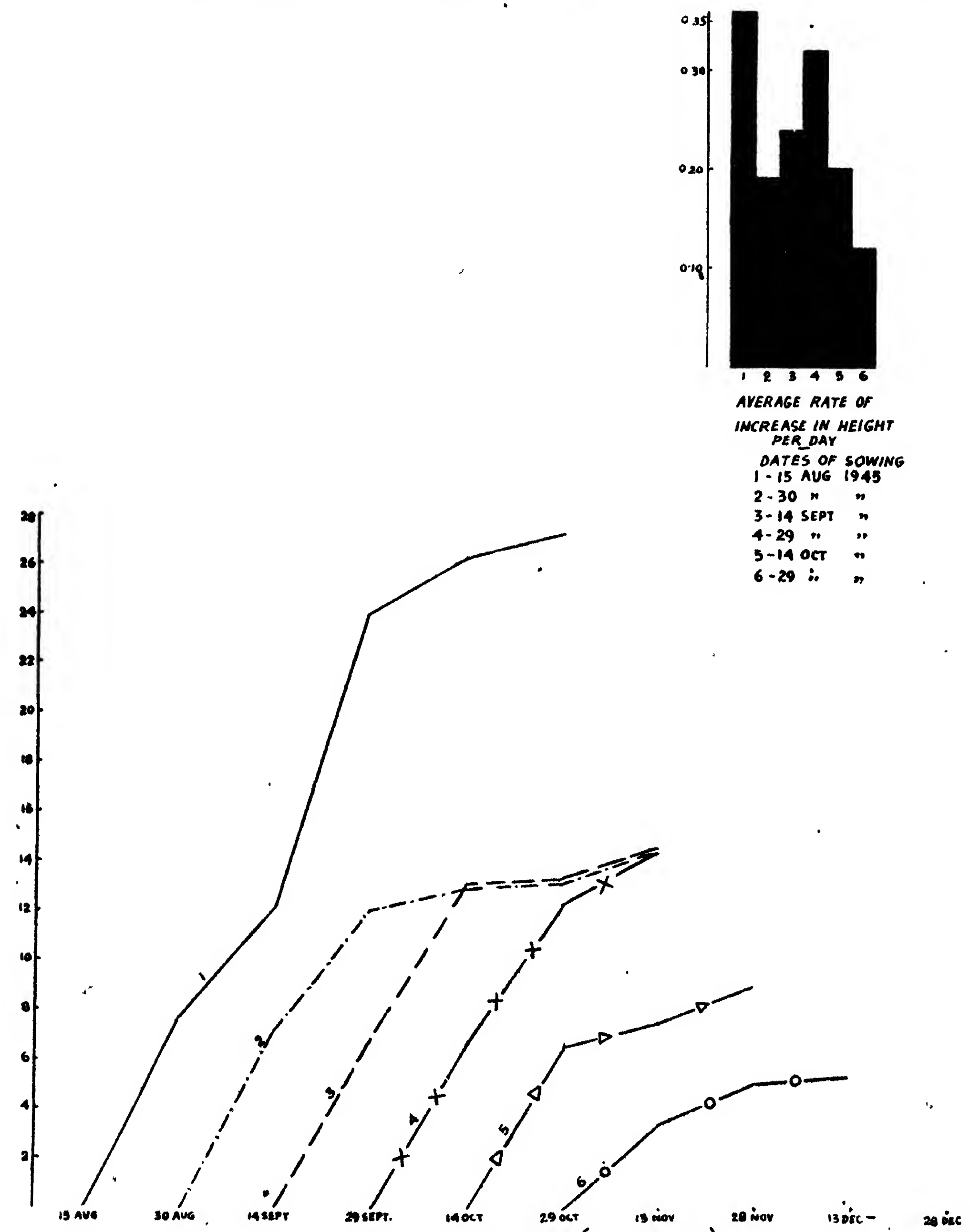
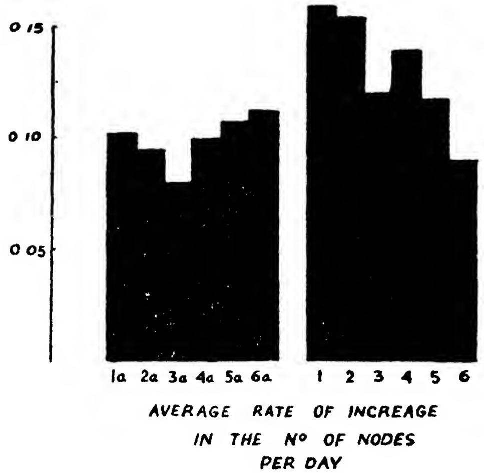


FIG II B (SONA MUNG)

G. IIB. Graphical representation of the number of nodes, increase in number after every 15 days, and average daily increase in the number of nodes.



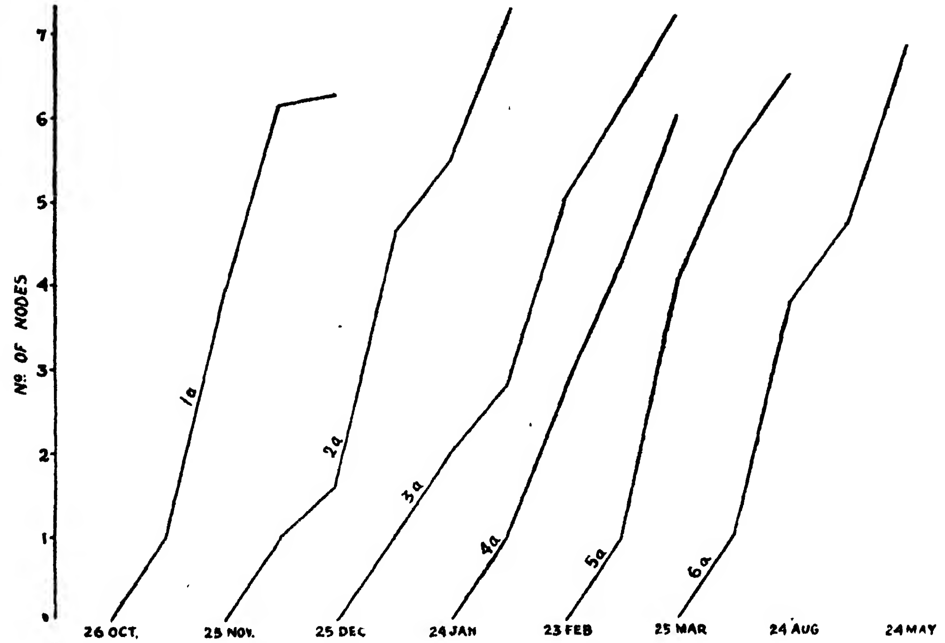


FIG III A (I P.28)

FIG. IIIA. Graphical representation of the number of nodes, increase in number after every 15 days and average daily increase in the number of nodes.

DATES OF SOWING

1a	-	26 Oct.	1944
2a	-	25 Nov.	"
3a	-	25 Dec.	"
4a	-	24 Jan.	1945
5a	-	23 Feb.	"
6a	-	25 Mar.	"
1	-	15 Aug.	"
2	-	30 "	"
3	-	14 Sept.	"
4	-	29 "	"
5	-	14 Oct.	"
6	-	29 "	"

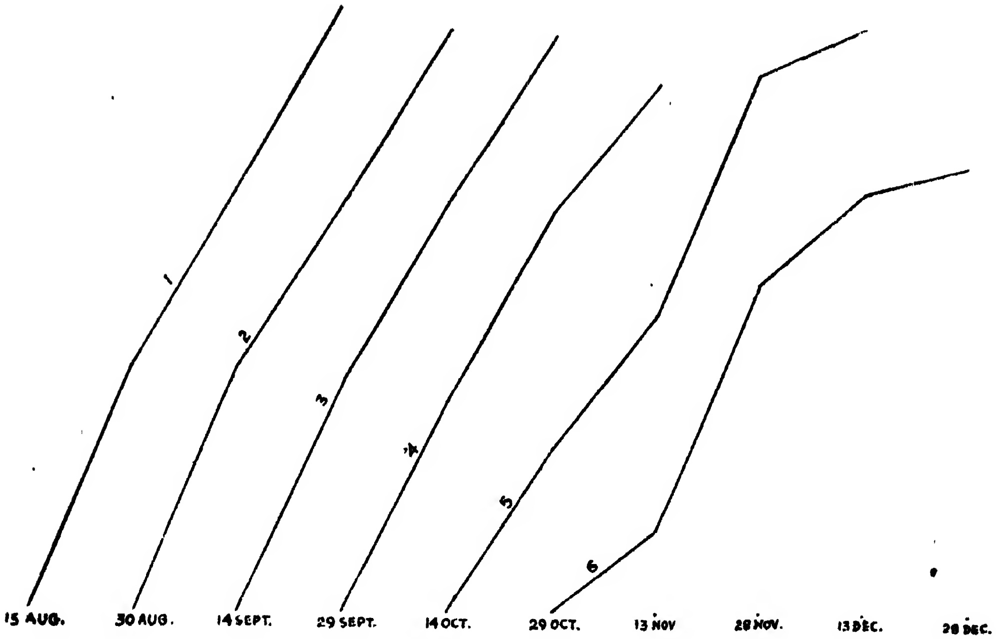


FIG. III A (I.P.28)

Fig. IIIA. Graphical representation of the number of nodes, increase in number after every 15 days and average daily increase in the number of nodes.

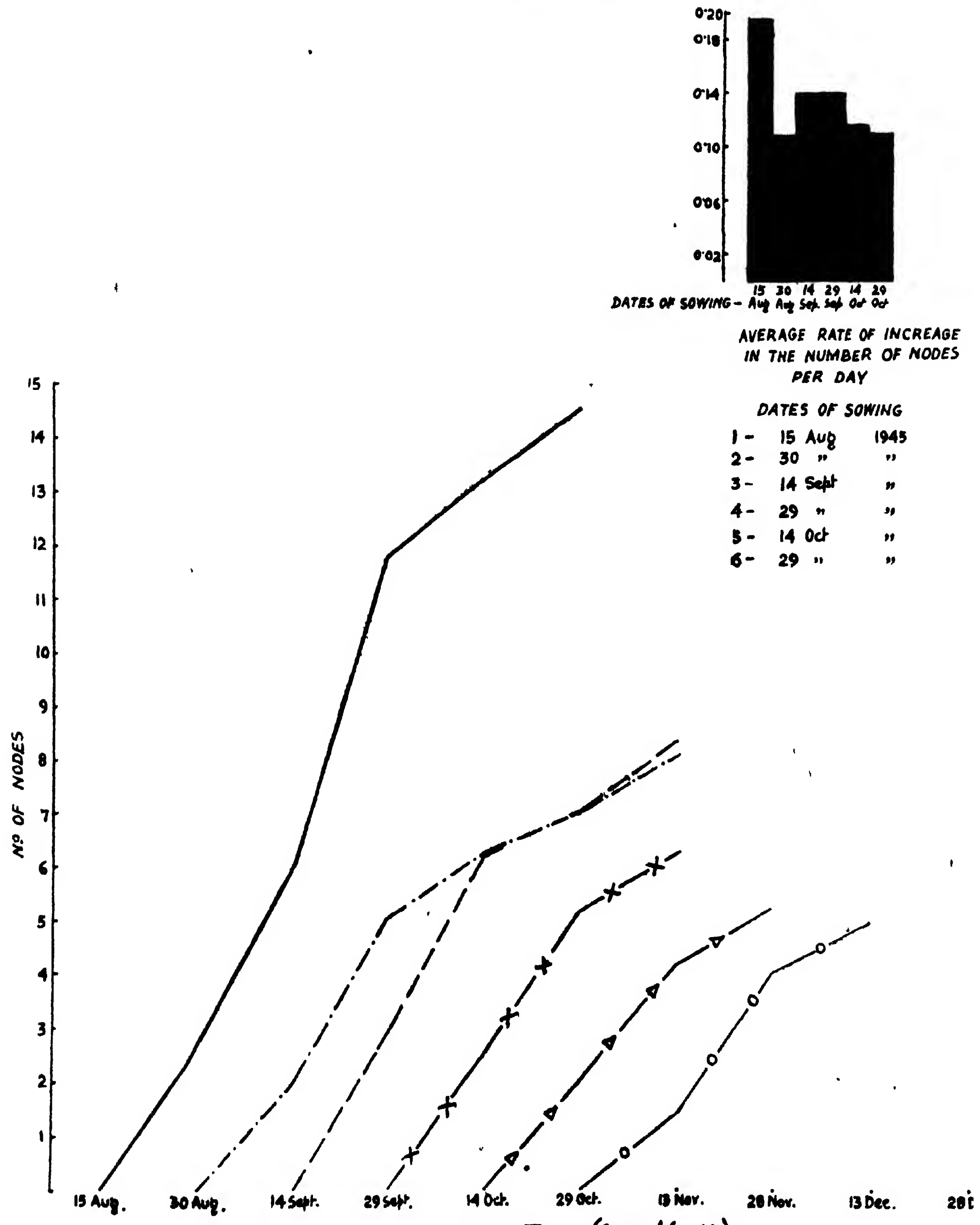


FIG III B (SONA MUNG)

FIG. IIIB. Graphical representation of the number of nodes, increase in number after every 15 days a average daily increase in the number of nodes.

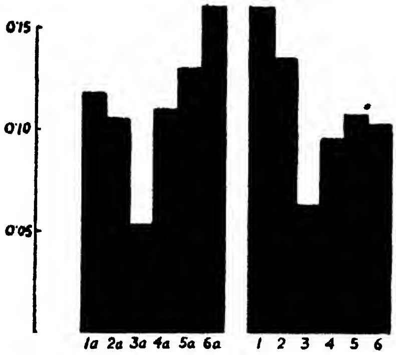
TABLE III-A
(*Mung I.P. 28*)

Dates of sowing	Number of nodes Days after sowing 1	30	45	60	75	90	Increase in the number of nodes between 15th-30th day	30th-45th day	45th-60th day	60th-75th day	75th-90th day	Average rate of increase per day
26 October 1944	1·00	3·89	6·11	6·21	..	..	2·89	2·22	0·10	..	..	0·103
25 November 1944	1·00	1·63	4·58	5·47	7·21	..	0·63	2·95	0·89	1·74	..	0·096
25 December 1944	1·00	2·00	2·80	5·00	..	7·20	1·00	0·80	2·20	..	2·20	0·080
24 January 1945	1·00	2·75	4·18	6·00	..	..	1·75	1·43	1·82	..	..	0·100
23 February 1945	1·00	4·05	5·55	6·50	..	..	3·05	1·50	0·95	..	..	0·108
25 March 1945	1·00	3·83	4·71	6·88	..	..	2·83	0·88	2·17	..	..	0·113
15 August 1945	3·00	5·10	7·33	..	..	..	2·10	2·23	..	..	..	0·162
30 August 1945	3·00	5·00	7·10	..	..	..	2·00	2·10	..	..	..	0·157
14 September 1945	2·80	5·00	7·00	7·37	..	..	2·20	2·00	0·37	..	..	0·122
29 September 1945	2·55	4·90	6·37	..	..	..	2·35	1·47	..	..	..	0·141
14 October 1945	2·00	3·60	6·55	7·10	..	..	1·60	2·95	0·55	..	..	0·118
29 October 1945	1·00	4·00	5·10	5·42	..	..	3·00	1·10	0·32	..	..	0·090

TABLE III-B
(*Sona Mung*)

Dates of sowing	Number of nodes Days after sowing 1	30	45	60	75	90	Increase in the number of nodes between 15th-30th day	30th-45th day	45th-60th day	60th-75th day	75th-90th day	Average rate of increase per day
15 August 1945	2·65	6·10	11·80	13·30	14·61	..	3·45	5·70	1·50	1·31	..	0·194
30 August 1945	2·00	5·05	6·30	7·10	8·15	..	3·03	1·27	0·80	1·05	..	0·108
14 September 1945	3·00	6·25	7·10	8·40	..	..	3·25	0·85	1·30	..	..	0·140
29 September 1945	2·50	5·20	6·30	..	..	..	2·70	1·10	..	..	..	0·140
14 October 1945	2·00	4·20	5·25	..	..	..	2·20	1·05	..	..	..	0·116
29 October 1945	1·45	4·05	5·00	..	..	..	2·60	0·95	1·15	..	..	0·111

The number of leaves on the plant, increase in the number every 15 days and the average dai rate of increase in the number (calculated by dividing the highest number reached by the tir required to attain it) are tabulated in Tables IV-A and IV-B and represented graphically in Fig IV-A and IV-B for I.P. 28 and *Sona Mung* respectively.



AVERAGE RATE OF INCREASE IN THE No. OF LEAVES PER DAY

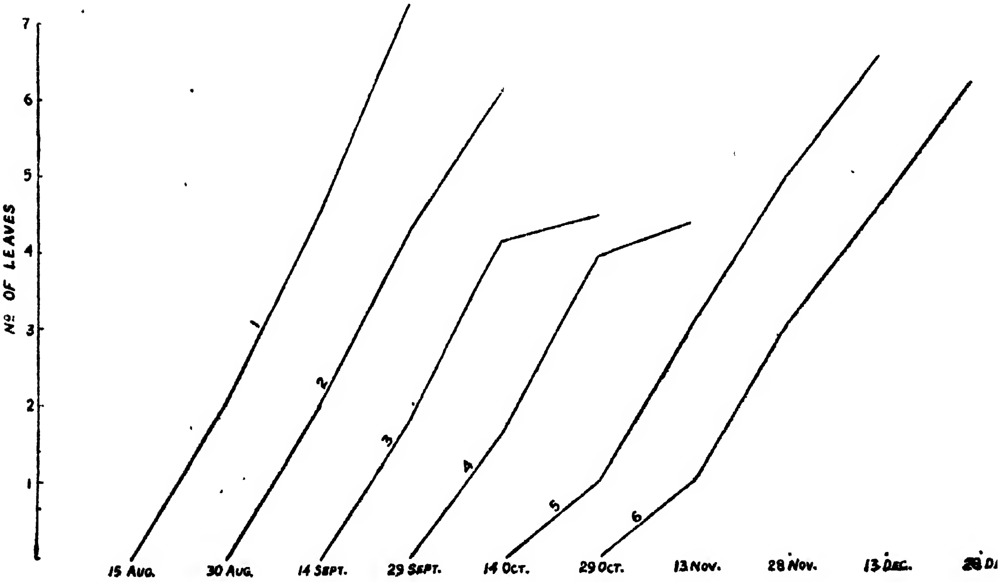


FIG. IV A. (I.P. 28)

FIG. IV A. Graphical representation of the number of leaves on the plant, increase in the number every days and average daily rate of increase in number.

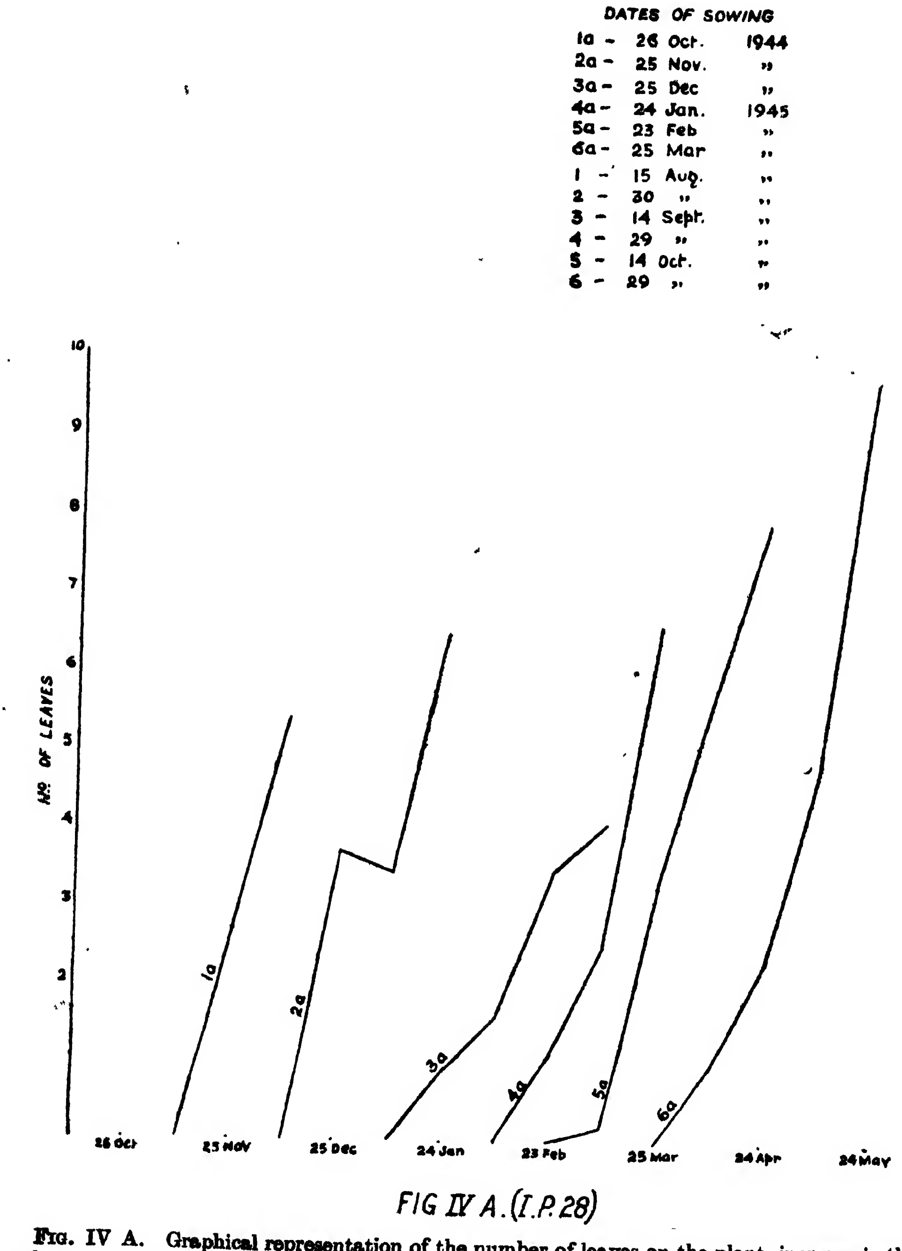


FIG. IV A. Graphical representation of the number of leaves on the plant, increase in the number every 15 days and average daily rate of increase.

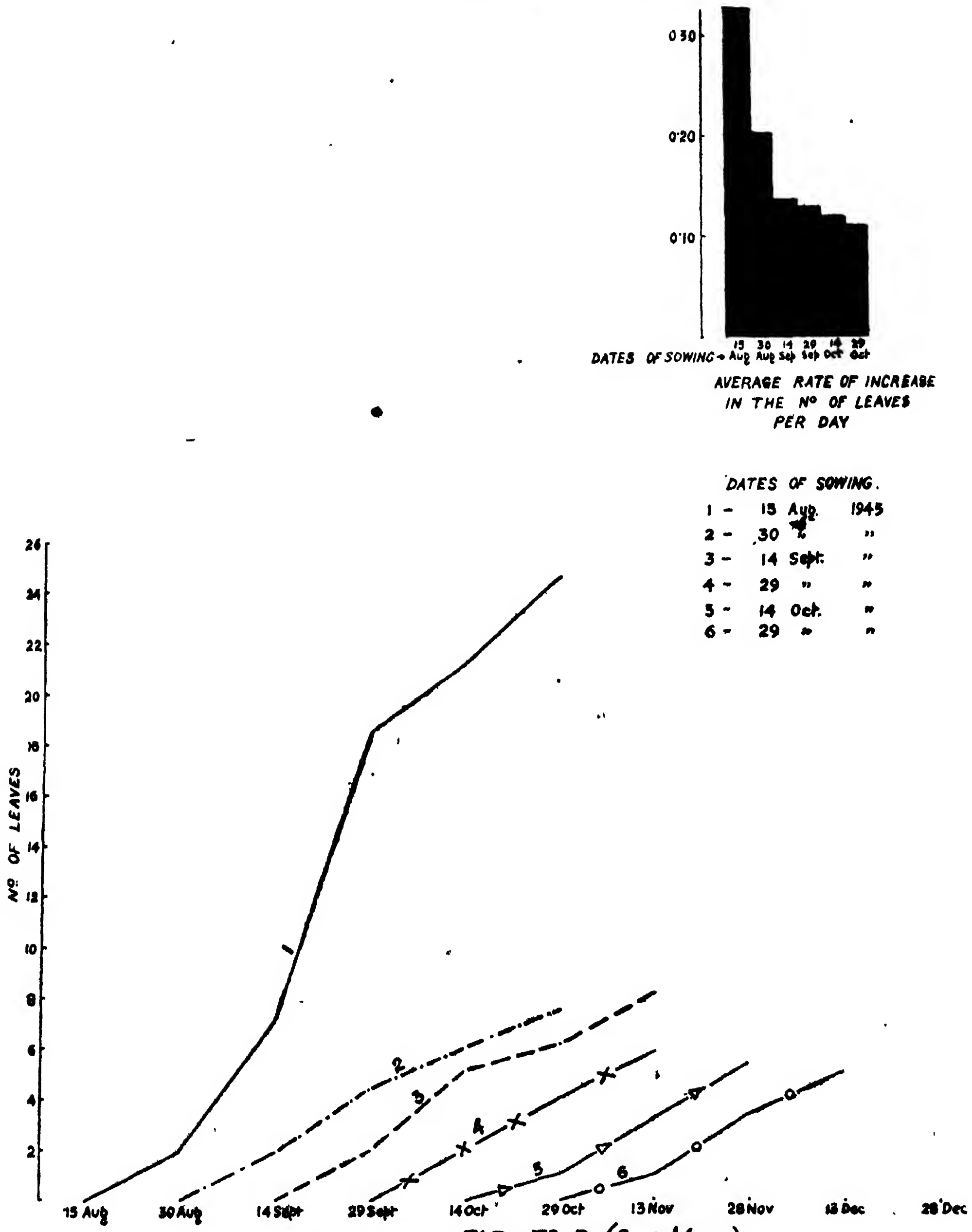


FIG IV B (SONA MUNG)

FIG. IV B. Graphical representation of the number of leaves on the plants increase in the number every 15 days and average daily rate of increase.

TABLE IV-A

(*Mung I.P. 28*)

Dates of sowing	Number of leaves on the plants Days after sowing						Increase in the number of leaves between					Average rate of increase per day
	15	30	45	60	75	90	15th to 30th	30th to 45th	45th to 60th	60th to 75th	75th to 90th	
26 October 1944	..	2·74	5·32	3·00	..	..	2·74	2·58	—2·32 *(Decrease)	..	..	0·118
25 November 1944	..	3·68	3·37	6·42	5·73	..	3·68	—0·31 *(Decrease)	3·05	—0·49 *(Decrease)	..	0·107
25 December 1944	..	0·90	1·60	3·44	4·07	3·00	0·90	0·70	1·84	0·63	—1·07 *(Decrease)	0·054
24 January 1945	..	1·10	2·50	6·60	..	..	1·10	1·40	4·10	..	..	0·110
23 February 1945	0·20	3·30	5·65	7·89	..	..	3·10	2·35	2·24	..	..	0·131
25 March 1945	1·00	2·33	4·85	9·77	..	..	1·33	2·52	4·92	..	..	0·162
15 August 1945	2·00	4·45	7·25	..	..	..	2·45	2·80	..	..	..	0·161
30 August 1945	2·00	4·30	6·15	..	..	..	2·30	1·85	..	..	..	0·136
14 September 1945	1·85	4·10	4·45	3·84	..	..	2·25	0·35	—0·61 *(Decrease)	..	.	0·064
29 September 1945	1·66	3·90	4·37	.	..	..	2·24	0·47	.	..	.	0·97
14 October 1945	1·00	3·05	4·94	6·55	..	..	2·05	1·89	1·61	..	.	0·109
29 October 1945	1·00	3·04	4·66	6·26	..	..	2·04	1·62	1 60	.		0·104

TABLE IV-B

(*Sona Mung*)

Dates of sowing	15	30	45	60	75	90	15th to 30th	30th to 45th	45th to 60th	60th to 75th	75th to 90th	Average rate of increase per day
15 August 1945	1·90	7·00	18·45	21·21	24·72	..	5·10	11·45	2·76	3·51	..	0·329
30 August 1945	1·85	4·30	6·00	7·50	15·20	..	2·45	1·70	1·50	7·70	..	0·220
14 September 1945	2·00	5·10	6·15	8·20	..	..	3·10	1·05	2·05	..	..	0·136
29 September 1945	2·00	4·00	5·85	..	..	..	2·00	1·85	..	..	..	0·130
14 October 1945	1·00	3·20	5·35	..	..	..	2·20	2·15	..	..	..	0·118
29 October 1945	1·00	3·40	5·10	..	..	..	2·40	1·70	1·15	..	..	0·113

* The decrease in the number of leaves were due to the shedding of some of them

The number of branches and the increase in number every 15 days are tabulated in Tables V-A and V-B for I.P. 28 and *Sona Mung* respectively.

[New branches were produced even after fruit formation, but there are no records after 'fruiting'.]

TABLE V-A

(*Mung I.P. 28*)

Dates of sowing	Number of branches Days after sowing						Increase in the number of branches between				
	15	30	45	60	75	90	15th to 30th day	30th to 45th day	45th to 60th day	60th to 75th day	75th to 90th day
26 October 1944	.	.	3·00	6·47	..	.	..	3·00	3·47	..	..
25 November 1944	.	1·21	1·65	4·68	5·53	.	1·21	0·44	3·03	0·85	..
25 December 1944	..	..		1·61	2·54	4·60	..	..	1·61	0·93	2·06
24 January 1945	..	.	..	3·40	..			..	3·40	..	..
23 February 1945	..	.	0·30	1·61	.	..	..	0·30	1·31	..	..
25 March 1945	..	.	..	2·11	.	..		..	2·11	..	..
15 August 1945	..	0·05	1·05	..	.	..	0·05	1·00	..	..	..
30 August 1945	..	..	0·73	..	..	..	..	0·73	..	..	..
14 September 1945	..	..	..	0·05	..	.	..	.	0·05	..	..
29 September 1945	..	..	0·66	..	..	..	.	0·66	..	..	..
14 October 1945	..	..	0·28	0·95	..	..	..	0·28	0·67	..	..
29 October 1945	..	.	0·16	0·42	..	..	.	0·16	0·26	..	..

TABLE V-B

(*Sona Mung*)

Dates of sowing	15	30	45	60	75	90	15th to 30th day	30th to 45th day	45th to 60th day	60th to 75th day	75th to 90th day
15 August 1945	..	1·45	3·95	5·10	5·50	..	1·45	2·50	1·15	0·40	..
30 August 1945	..	..	..	1·05	2·55	..	..	..	1·05	1·50	..
14 September 1945	..	..	0·10	1·55	.	..	.	0·10	1·45	..	..
29 September 1945	..	..	0·56	..	..	..	..	0·56	..	..	..
14 October 1945	..	..	0·95	..	..	..	..	0·95		..	..
29 October 1945	..	0·35	1·25	..	.	..	0·35	0·90	0·30	..	..

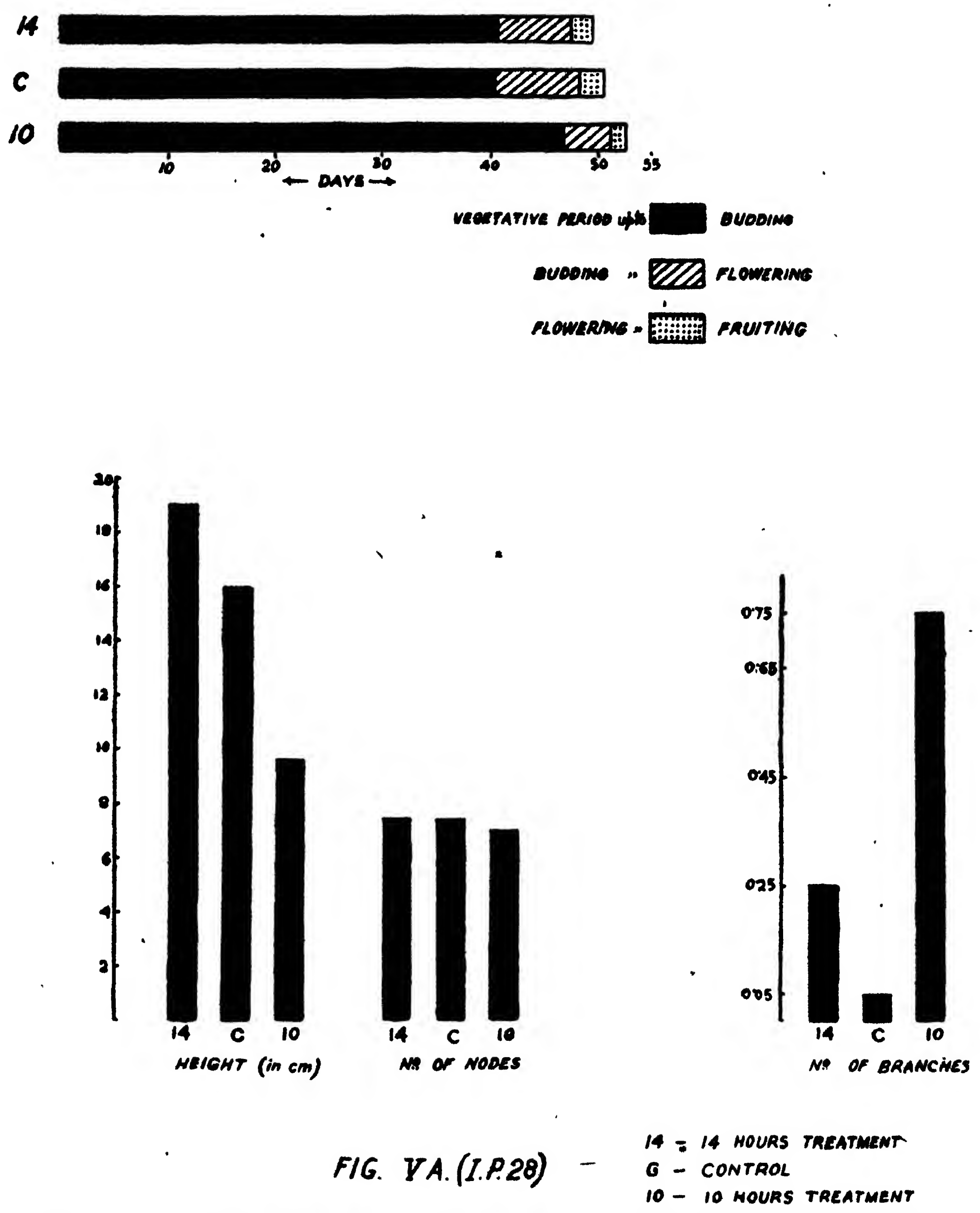


FIG. V A. Graphical representation of the mean data for budding, flowering, and fruiting time, and the total height, number of nodes, leaves and branches.

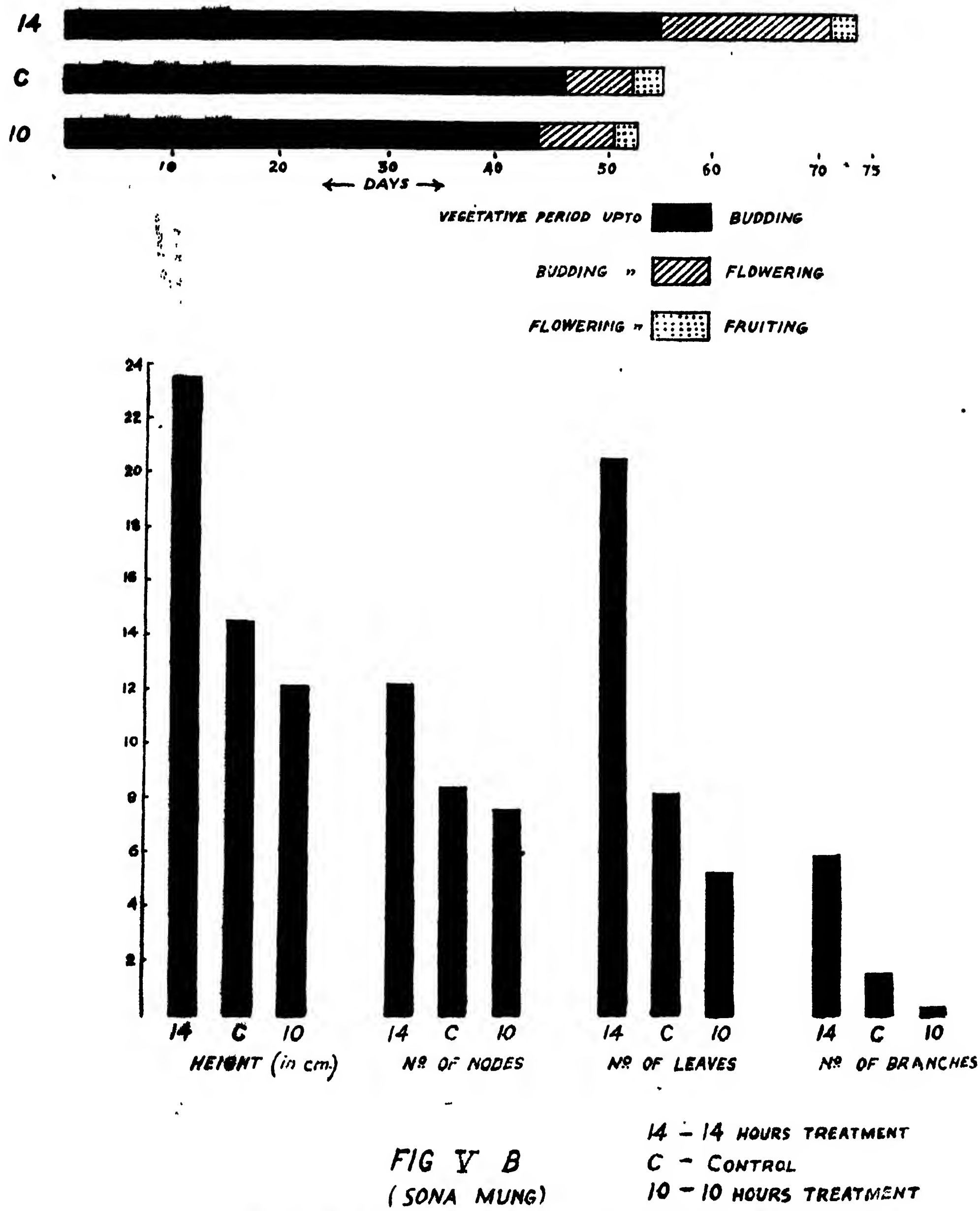


FIG. V B. Graphical representation of the mean data for budding, flowering and fruiting time, and the total height, number of nodes, leaves and branches.

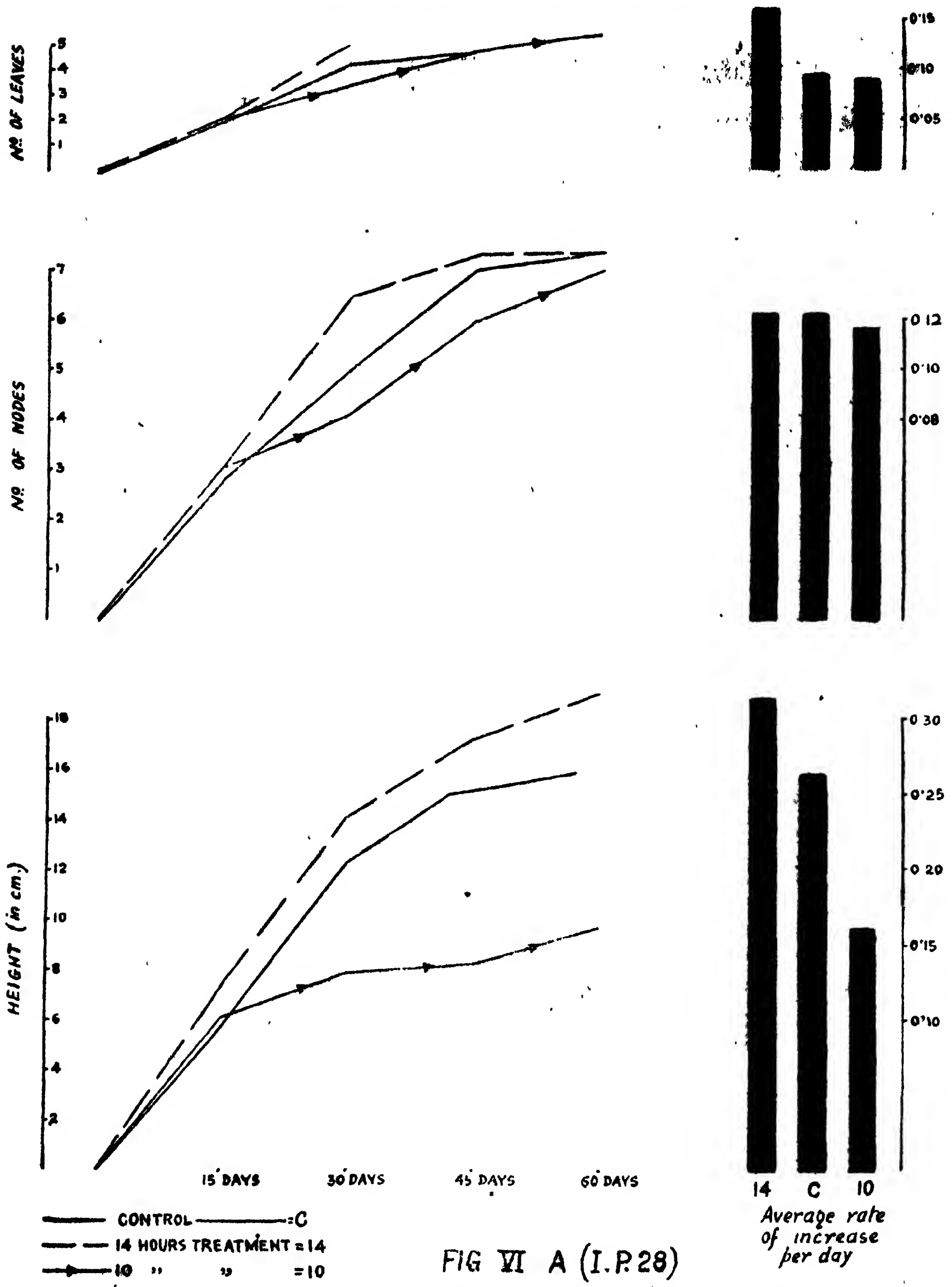


FIG. VI A. Graphical representation of heights, the number of nodes, leaves and branches, the increase every 15 days, and average rate of increase per day.

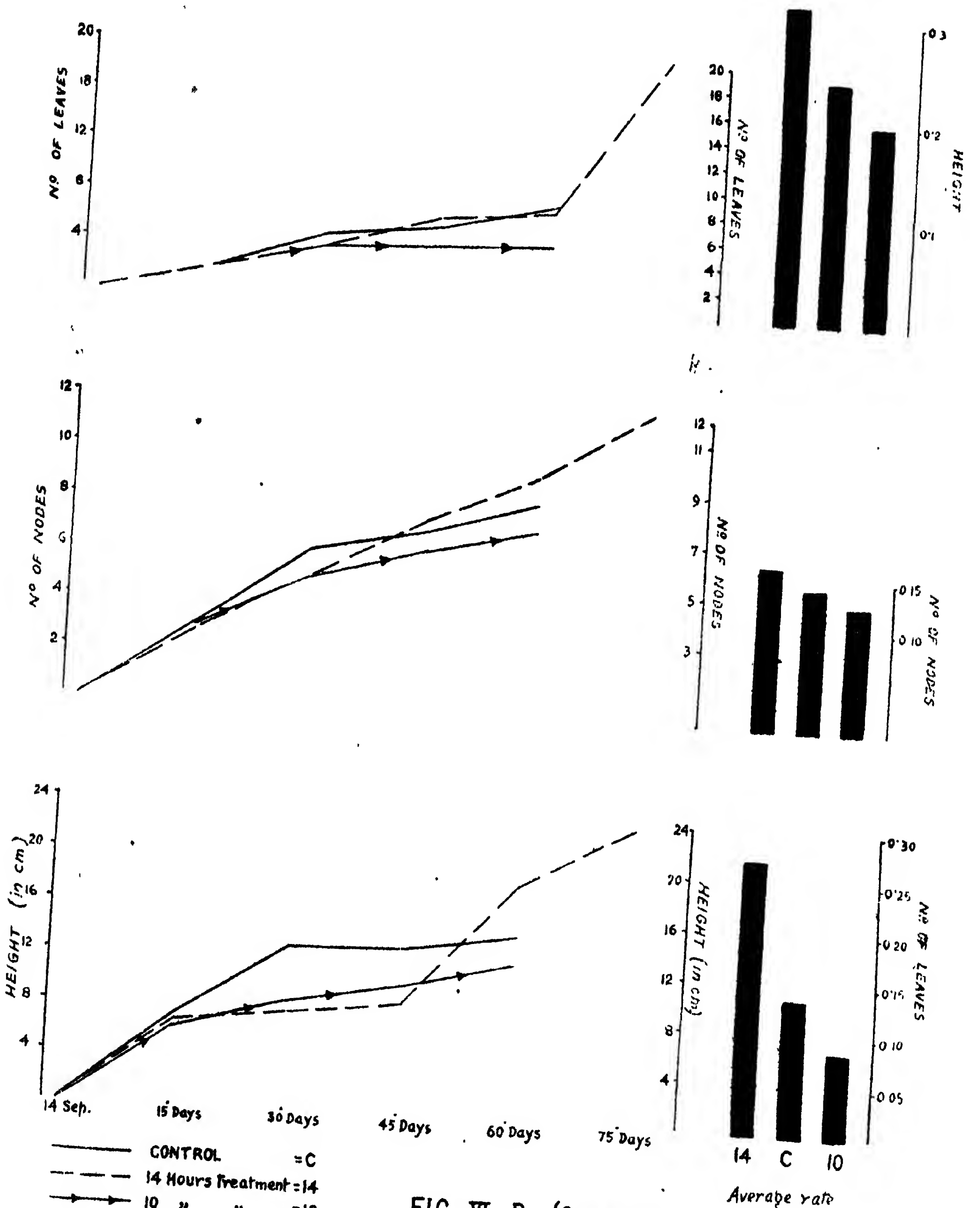


FIG. VI B (SONA MUNG)

Fig. VI B. Graphical representation of heights, the number of nodes, leaves and branches, the increase every 15 days, and average rate of increase per day.

PHOTOPERIODISM

The mean data for budding, flowering, and fruiting time, and the total height number of nodes, leaves and branches formed are tabulated in Tables VI-A and VI-B and graphically represented in **Figs. V-A and V-B** for I. P. 28, and *Sona Mung* respectively. The heights, the number of nodes, leaves, and branches, the increases every 15 days, and the average rate of increase per day, are given in Tables VII-A and VII-B and graphically represented in Figs. VI-A and VI-B for I. P. 28 and *Sona Mung* respectively.

The light periods to which the plants were treated were 10 hours and 14 hours, the effects of which on the plants are compared with the control which was exposed to normal light period of the days.

TABLE VI-A

(*Mung I. P. 28*)

Treatment	Dates of			Days after sowing			Days between		Totals reached			
	Budding	Flowering	Fruiting	Budding	Flowering	Fruiting	Budding and flowering	Flowering and fruiting	Height	Nodes	Leaves	Branches
14 hours	24 October	1 November	1 November	40·65	47·55	49·70	6·90	2·15	18·95	7·37	*	0·25
Control	24 October	2 November	4 November	40·45	48·55	50·72	8·10	2·17	15·87	7·37	*	0·05
10 hours	31 October	4 November	6 November	46·87	51·25	52·75	4·38	1·50	9·60	7·00	5·40	0·75

Treatment	Dates of			Earliness (+) or lateness (—) to the control				Increase (+) or decrease (—) over the control		
	Budding	Flowering	Fruiting	Budding	Flowering	Fruiting	Height	Nodes	Leaves	Branches
14 hours	24 October	1 November	3 November	—0·20	—1·00	+1·02	+3·08	—	—	+0·20
Control	24 October	2 November	4 November	—	—	—	—	—	—	—
10 hours	31 October	4 November	6 November	—6·42	—2·70	—2·03	—6·27	—0·37	—	+0·70

*Total number of leaves decreased at the final observation as many of them were shed before fruiting

TABLE VI-B

(*Sona Mung*)

—	Dates of			Days after sowing			Days between		Totals reached			
	Budding	Flowering	Fruiting	Budding	Flowering	Fruiting	Budding and flowering	Fruiting and flowering	Height	Nodes	Leaves	Branches
14 hours	8 November	24 November	27 November	55·25	71·33	73·50	16·08	2·17	23·47	12·24	20·47	5·88
Control	30 October	6 November	9 November	46·10	52·84	55·47	6·74	2·63	14·53	8·40	8·20	1·55
10 hours	28 October	4 November	6 November	44·10	51·09	53·10	6·99	2·10	12·15	7·60	5·25	0·35

—	Dates of			Earliness (+) or lateness (—) to the control			Increase (+) or decrease (—) over the control			
	Budding	Flowering	Fruiting	Budding	Flowering	Fruiting	Height	Nodes	Leaves	Branches
14 hours	8 November	24 November	27 November	—9·15	—18·49	—18·03	+8·94	+3·84	+12·27	+4·33
Control	30 October	6 November	9 November	—	—	—	—	—	—	—
10 hours	28 October	4 November	6 November	+2·00	+1·75	+2·37	—2·38	—0·80	—2·95	—1·20

TABLE VII-A

(*Mung I. P. 28*)

Treatment	Totals reached				Increase (+) or decrease (—) over the control				Increases between			Average rate of increase per day
	Days after sowing				Days after sowing				15th to 30th day	30th to 45th day	45th to 60th day	
	15	30	45	60	15	30	45	60				
Height												
14 hours	7·35	14·11	17·20	18·95	+1·52	+1·85	+2·25	+3·08	6·76	3·09	1·75	0·316
Control	5·83	12·26	14·95	15·87	—	—	—	—	6·43	2·69	0·92	0·264
10 hours	6·13	7·85	8·33	9·60	+0·30	—4·41	—6·62	—6·27	1·72	0·48	1·27	0·160
Number of nodes												
14 hours	3·00	6·42	7·30	7·37	+0·20	+1·42	+0·30	—	3·42	0·88	0·07	0·122
Control	2·80	5·00	7·00	7·37	—	—	—	—	2·20	2·00	0·37	0·122
10 hours	3·00	4·18	6·00	7·00	+0·20	—0·82	—1·00	—0·37	1·18	1·82	1·00	0·116
Number of leaves												
14 hours	2·00	4·82	4·80	3·16	+0·15	+0·72	—	—	2·82	—0·02	—1·64	0·160
Control	1·85	4·10	4·45	3·84	—	—	—	—	2·25	0·35	—0·61	0·098
10 hours	2·00	3·25	4·50	5·40	+0·15	—0·85	—	—	1·25	0·25	0·90	0·090
Number of branches												
14 hours	—	—	—	0·25	—	—	—	+0·20	—	—	0·25	—
Control	—	—	—	0·05	—	—	—	—	—	—	0·05	—
10 hours	—	—	—	0·75	—	—	—	+0·70	—	—	0·75	—

TABLE VII-B

(Sona Mung)

Height

Treatment	Totals reached: Days after sowing 15	30	45	60	75	Increase (+) or decrease (—) over the control: Days after sowing 15	30	45	60	Increases between: 15th to 30th day	30th to 45th day	45th to 60th day	60th to 75th day	Average rate of increase per day
14 hours	6·71	7·85	8·75	18·48	23·47	—0·14	—5·08	—4·53	+3·95	1·14	0·90	9·73	4·99	0·316
Control	6·85	12·93	13·28	14·53	—	—	—	—	—	6·08	0·35	1·25	—	0·242
10 hours	6·38	8·91	10·25	12·15	—	—0·47	—4·02	—3·03	—2·38	2·53	1·34	1·90	—	0·202
Number of nodes														
14 hours	2·85	5·00	7·45	9·45	12·24	(—)0·15	(—)1·15	(+)0·35	(+)1·05	2·25	2·35	2·00	2·79	0·163
Control	3·00	6·25	7·00	8·40	—	—	—	—	—	3·25	0·85	1·30	—	0·140
10 hours	3·00	5·11	6·70	7·60	—	—	(—)1·14	(—)0·40	(—)0·80	2·11	1·60	0·90	—	0·126
Number of leaves														
14 hours	1·95	4·25	6·90	7·90	20·47	—0·05	—0·85	+0·75	—0·30	2·30	1·65	1·00	12·57	0·272
Control	2·00	5·10	6·15	8·20	—	—	—	—	—	3·10	1·05	2·05	—	0·136
10 hours	2·00	4·12	4·75	5·25	—	—	—0·98	—1·40	—2·95	2·12	0·63	0·50	—	0·087
Number of branches														
14 hours	—	—	0·30	1·85	5·88	—	—	+0·20	+0·30	—	0·30	1·55	4·03	—
Control	—	—	0·10	1·55	—	—	—	—	—	—	0·10	1·45	—	—
10 hours	—	—	0·15	0·35	—	—	—	+0·05	—1·20	—	0·15	0·20	—	—

VERNALIZATION

Effect of pre-sowing low temperature treatment (2°C.—4°C.) for 10 days

The mean data for the time of budding, flowering, and fruiting, the total height reached, number of nodes, leaves, and branches formed, are given in the Tables VIII-A and VIII-B and represented graphically in Figs. VII-A and VII-B for I. P. 28 and *Sona Mung* respectively. The heights, number of nodes, leaves, and branches, the increase every 15 days, and the average rate of increase per day are tabulated in Tables IX-A and IX-B and graphically represented in Figs. VIII-A and VIII-B for I. P. 28 and *Sona Mung* respectively.

TABLE VIII-A

(*Mung I. P. 28*)

Treatment	Dates of			Days after sowing			Days between		Totals reached			
	Budding	Flowering	Fruiting	Budding	Flowering	Fruiting	Budding and flowering	Flowering and fruiting	Height	Nodes	Leaves	Branches
10 days	27 October	2 November	4 November	43·15	48·84	50·68	5·69	1·84	16·60	7·66	3·53*	0·13
Control	24 October	2 November	4 November	40·45	48·55	50·72	8·10	2·17	15·87	7·37	3·84*	0·05

Treatment	Budding	Flowering	Fruiting	Budding	Flowering	Fruiting	Height	Nodes	Leaves	Branches
10 days	27 October	2 November	4 November	—2·70	—0·29	+0·04	+0·73	+0·29	—	+0·08
Control	24 October	2 November	4 November	—	—	—	—	—	—	—
* Due to shedding of leaves				Earliness (+) or lateness (—) to the control			Increase (+) or decrease (—) over the control			

TABLE VIII-B

(*Sona Mung*)

10 days	1 November	4 November	6 November	48·84	51·38	53·35	2·54	1·97	11·85	8·60	7·85	1·45
Control	30 October	6 November	9 November	46·10	52·84	55·47	6·74	2·63	14·53	8·40	8·20	1·55

10 days	2 October	4 November	6 November	—2·74	+1·46	+2·12	—2·68	—0·20	—0·85	— 0·10
Control	30 October	6 November	9 November	—	—	—	—	—	—	—

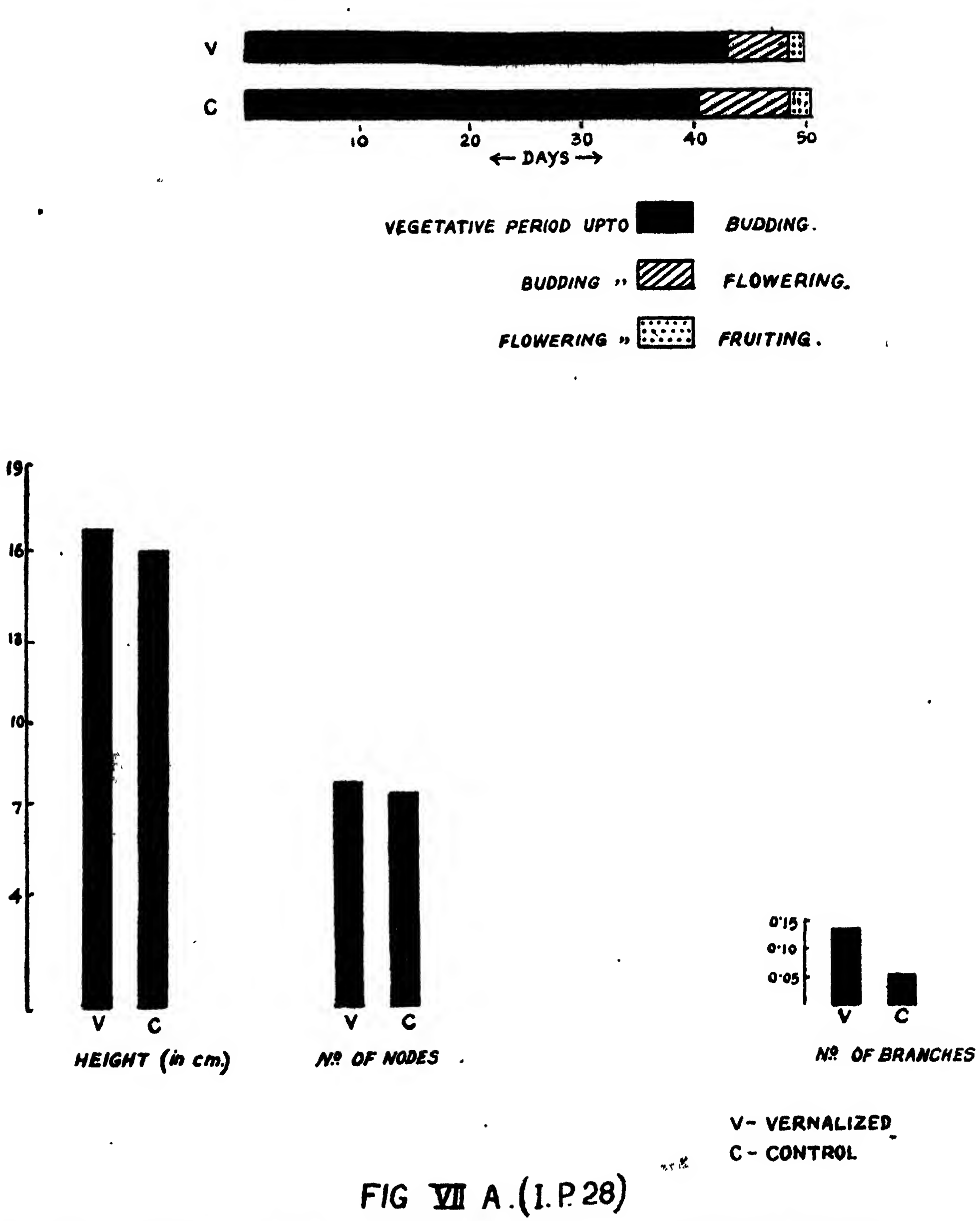


FIG. VII A. Graphical representation of mean data for the time of budding, flowering and fruiting, the total height, number of nodes, leaves and branches

I

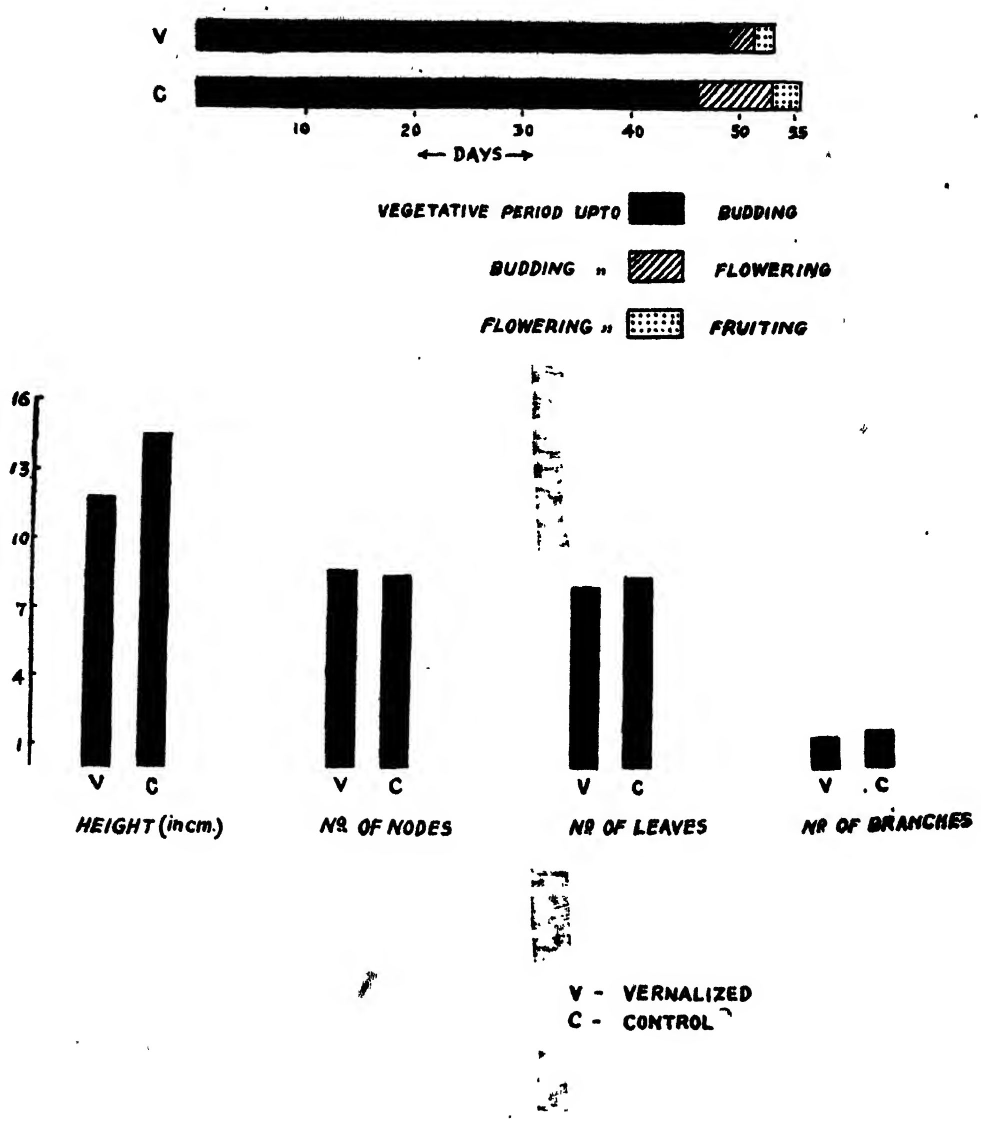


FIG VII B (SONA MUNG)

FIG. VII B. Graphical representation of mean data for the time of budding, flowering and fruiting, the total height, the number of nodes, leaves and branches

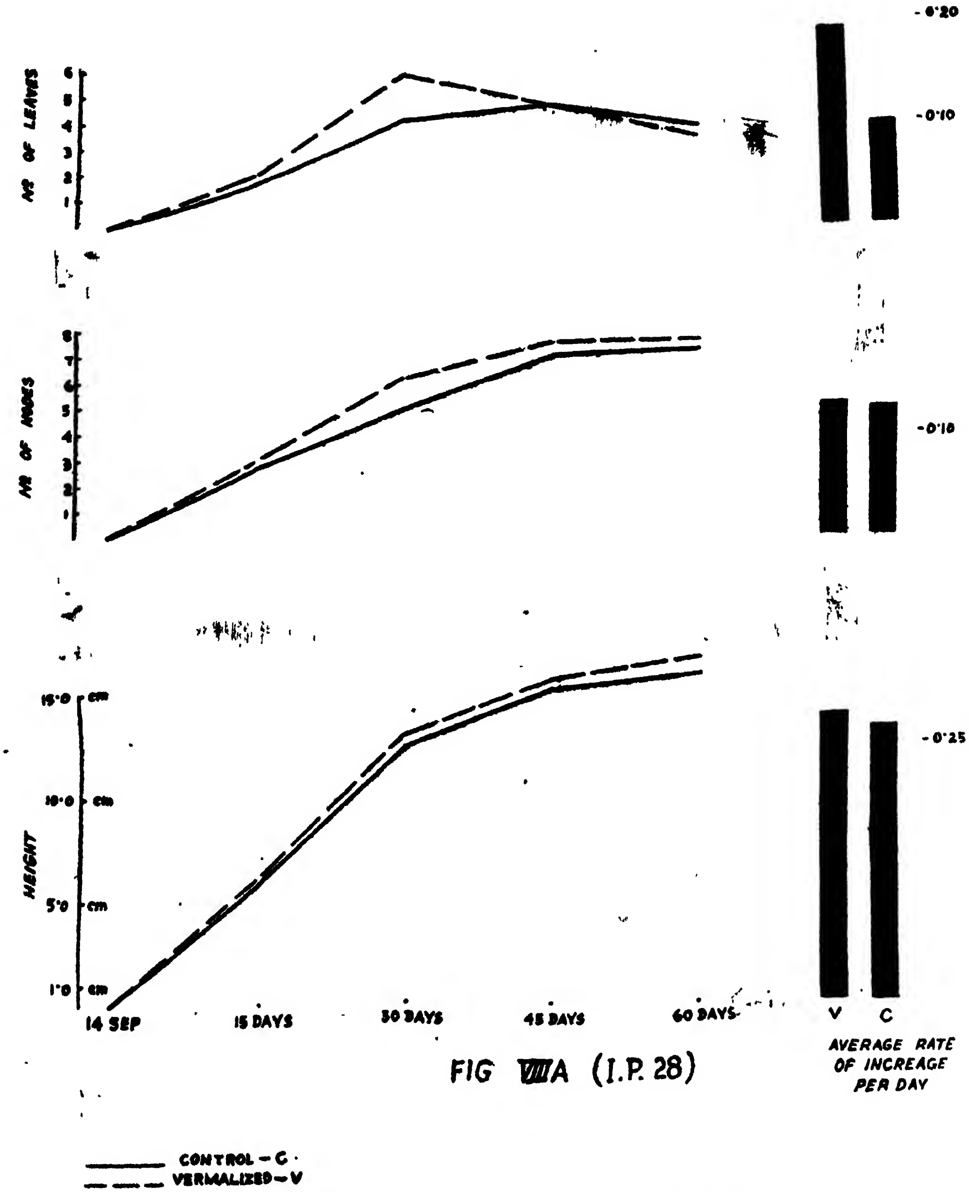


Fig. VIII A. Graphical representation of heights, number of nodes, leaves and branches, the increase every 15 days, and average rate of increase per day

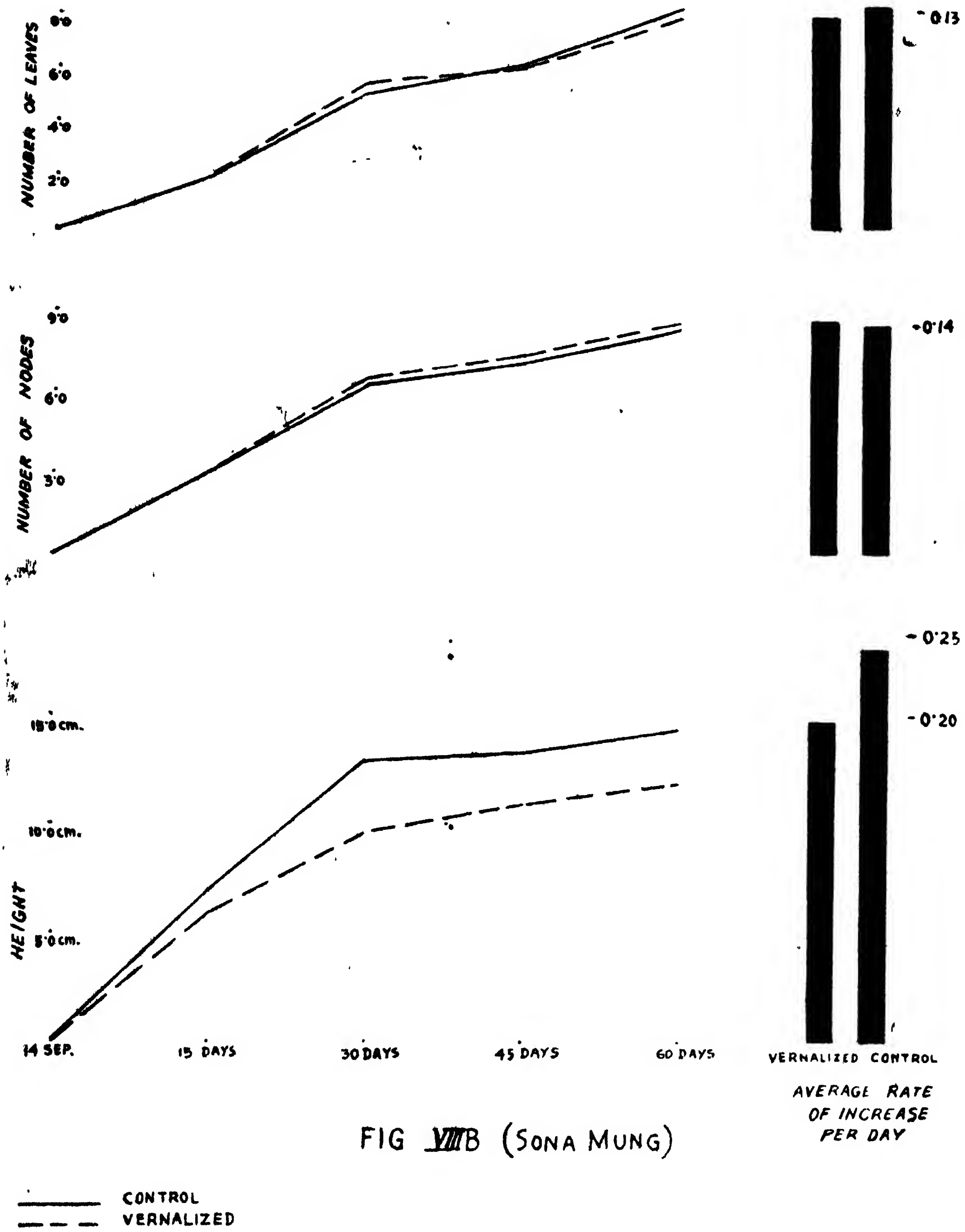


FIG. VIII B. Graphical representation of heights, number of nodes, leaves and branches, the increase every 15 days, and average rate of increase per day

TABLE IX-A

(*Mung I. P. 28*)

Treatment	Totals reached Days after sowing				Increase (+) or decrease (—) over the control Days after sowing				Increases between			Average rate of increase per day
	15	30	45	60	15	30	45	60	15th to 30th days	30th to 45th days	45th to 60th days	
Height												
10 days	6·03	12·99	15·43	16·60	+0·20	+0·73	+0·48	+0·73	6·96	2·44	1·17	0·276
Control	5·83	12·26	14·95	15·37	—	—	—	—	6·43	2·69	0·92	0·264
Number of nodes												
10 days	3·05	6·10	7·40	7·66	+0·25	+1·10	+0·40	+0·29	3·05	1·30	0·26	0·127
Control	2·80	5·00	7·00	7·37	—	—	—	—	2·20	2·00	0·37	0·122
Number of leaves												
10 days	2·05	5·73	4·40	3·53	+0·20	+1·63	—	—	3·68	—1·33*	—0·87*	0·191
Control	1·85	4·10	4·45	3·84	—	—	—	—	2·25	0·34	—0·61*	0·098
Number of branches												
10 days	—	—	—	0·13	—	—	—	+0·08	—	—	0·13	—
Control	—	—	—	0·05	—	—	—	—	—	—	0·05	—

*Due to shedding of leaves

TABLE IX-B

(*Sona Mung*)

Treatment	Totals reached Days after sowing				Increase (+) or decrease (—) than the control Days after sowing				Increase between			Average rate of increase per day
	15	30	45	60	15	30	45	60	15th to 30th day	30th to 45th day	45th to 60th day	
Height												
10 days	5·92	9·61	10·80	11·85	—0·93	—3·32	— 2·48	—2·68	3·69	1·19	1·05	0·197
Control	6·85	12·93	13·28	14·53	—	—	—	—	6·08	0·35	1·25	0·242
Number of nodes												
10 days	3·00	6·50	7·40	8·60	—	+0·25	+0·30	+0·20	3·50	0·90	1·20	0·143
Control	3·00	6·25	7·10	8·40	—	—	—	—	3·25	0·85	1·30	0·140
Number of leaves												
10 days	2·00	5·45	6·10	7·85	—	+0·35	—0·05	—0·35	3·45	0·65	1·75	0·130
Control	2·00	5·10	6·15	8·20	—	—	—	—	3·10	1·05	2·05	0·136
Number of branches												
10 days	—	0·10	0·65	1·45	—	+0·10	+0·55	—0·10	0·10	0·55	0·80	—
Control	—	—	0·10	1·55	—	—	—	—	—	0·10	1·45	—

Meteorological data

The mean values for every 15 days of the different meteorological factors, viz., the maximum and minimum temperatures, rainfall, relative humidity, daylength, and the total hours of bright sunshine are tabulated in Table X, and graphically represented in Fig. IX.

Table X

Meteorological data

Dates	Maximum tempera-ture	Minimum Tempera-ture	Rainfall	Relative humidity	Length of day	Total hours of bright sunshine
					Hrs. Min.	
1 December 1944	83·5	58·4	0·00	61·6	10—35	8·9
15 December 1944.						
1 January 1945	82·1	57·8	0·00	58·2	10—35	8·9
15 January 1945	75·2	53·7	0·06	62·4	10—47	9·2
1 February 1945	79·9	54·4	0·00	51·1	10—56	9·1
15 February 1945	84·2	58·8	0·02	51·3	11—12	9·2
1 March 1945	85·2	59·0	0·00	48·8	11—32	9·5
15 March 1945	92·6	67·0	0·30	44·2	11—48	9·4
1 April 1945	96·7	75·3	0·00	56·4	12—14	9·9
15 April 1945	95·6	77·4	0·03	59·7	12—32	9·0
1 May 1945	92·2	72·0	0·23	62·8	12—51	8·9
15 May 1945	96·8	79·0	0·14	67·9	13—00	9·7
1 June 1945	95·0	77·5	0·14	70·8	13—18	7·9
15 June 1945	95·8	82·0	0·02	71·9	13—15	6·4
1 July 1945	93·8	79·2	0·51	84·5	13—15	3·5
15 July 1945	89·8	79·9	0·29	82·5	13—09	5·2
1 August 1945	92·0	80·3	0·19	78·3	12—57	4·9
15 August 1945	92·4	80·5	0·17	78·3	12—53	4·3
1 September 1945	89·4	79·3	0·28	88·0	12—34	5·3
15 September 1945	90·1	79·9	0·13	81·4	12—15	4·3
1 October 1945	90·8	78·5	0·59	85·0	11—53	4·5
15 October 1945	90·6	76·9	0·13	76·6	11—34	6·7
1 November 1945	89·1	72·0	0·59	85·5	11—26	6·0
15 November 1945	86·6	68·0	..	64·8	10—56	9·2
1 December 1945	83·1	60·2	0·00	59·6	10—42	9·7
15 December 1945	80·2	57·0	0·00	58·1	10—36	9·3
31 December 1945	77·06	52·7	0·00	60·1	10—35	9·3

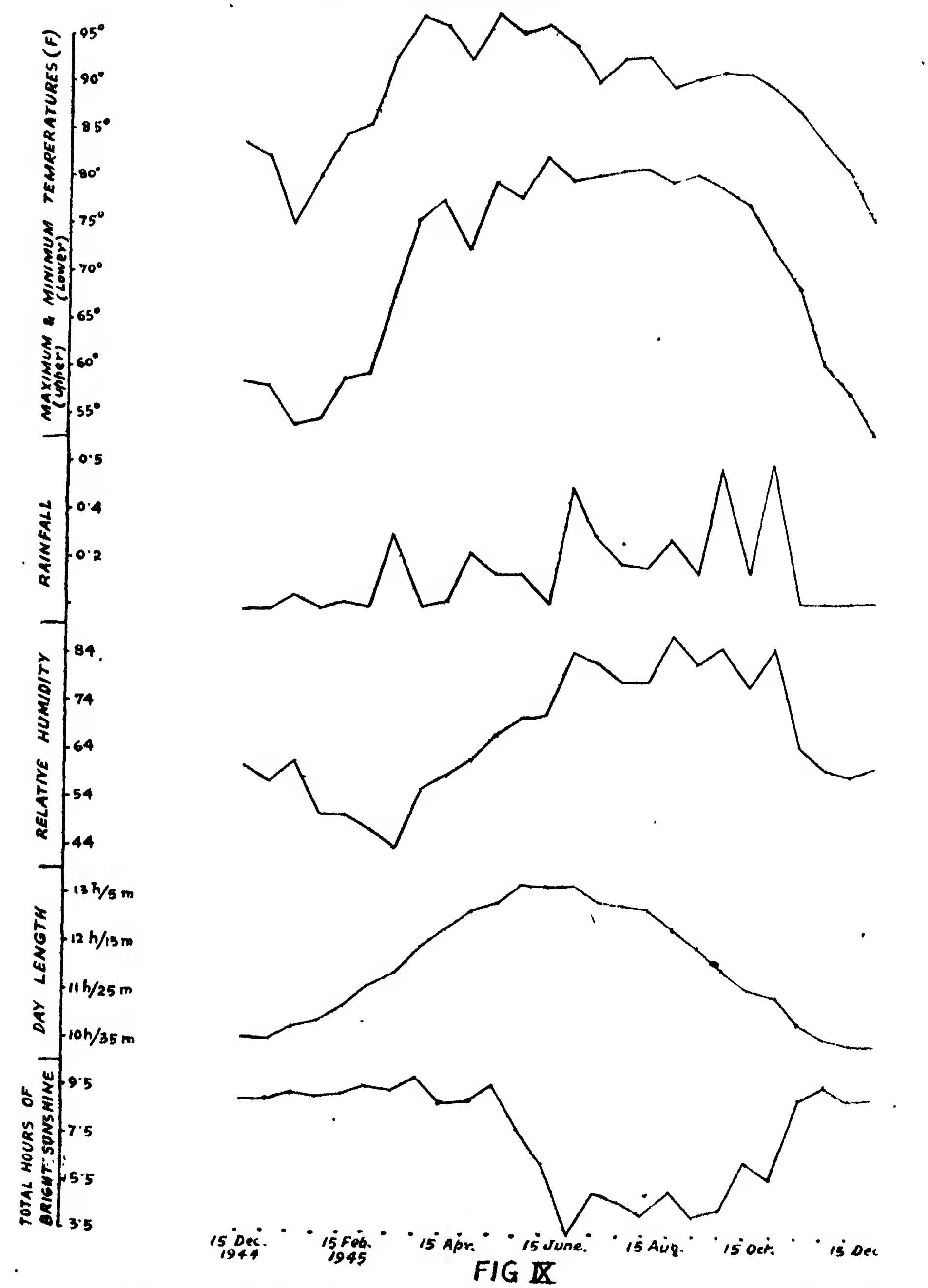


FIG IX

FIG. IX. Graphical representation of mean values for every 15 days of the different meteorological factors.

Discussion

Growth and development of a plant depend upon several environmental factors which act simultaneously. It is impossible to interpret the behaviour of a plant with regard to a particular environmental factor if all the factors were not kept under strict control. When the plants are sown at different times of the year, they are exposed to the natural variation of the environmental factors in which practically all the factors vary simultaneously and the plants of subsequent sowings are exposed to the same environmental factors at different ages. A clear correlation of the variation in growth and development of the plants to the different meteorological factors is, thus, not possible. An attempt may, however, be made to find out the dominant factor or factors for the promotion of vegetative and reproductive growth.

In both the varieties, the vegetative growth of the plants decreased as the sowing was delayed from 15 August to 29 October 1945. During this period (extending upto 15 December 1945) the daily light period gradually decreased from 12 hrs. 53 minutes to 10 hrs. 36 minutes, the maximum and the minimum temperature from 92·4° and 80·5° F. to 80·2° and 57·0° F. respectively, the rainfall remained high till the 1 November after which dry period set in without any rainfall and the humidity gradually fell to 58·1. The period of bright sunshine rose from 4·3 to 9·7 hrs. from 15 August to 1 December 1945. The growth in height fell to comparatively low values in the last two sowings—the 14 and the 29 October, 1945. In *Sona Mung* the fall in height from the 15 August to the 30 August sowing was very great. A slight increase was noticed in the total height in the 14 September sowing of *Sona Mung*.

Amongst the sowings from 16 October 1944 to 25 March 1945, of I. P. 28, the lowest growth in height was recorded for the 24 January sowing, the next higher was the 26 October sowing, the next higher was the 25 December sowing, the next higher was the 25 November sowing and in 23 February and 25 March sowings the heights were comparatively much higher than the other sowings. The daily light period decreased gradually from 11 hrs. 15 minutes to 10 hrs. 35 minutes between the 1 November 1944 to 1 January 1945 after which it gradually rose upto 13·00 hours on the 15 May. The maximum and minimum temperature gradually decreased from 83·5° F. and 58·4° F. to 75·2°F. and 53·7°F. from 15 December, 1944 to 15 January 1945 and from 15 January gradually rose to 96·7° F. and 75·3° F. on 1 April and were 96·8° F. and 79·0° F. respectively on 15 May with an intermediate value on the 1 May. Rainfall was *nil* after 15 November 1944 and the humidity gradually decreased and became only 44·2 on the 15th March 1945. The period of bright sunshine reached the highest value (9·9) on the 1st April 1945.

It was noticed that the vegetative growth was particularly retarded in the October sowing. This may be due to the shortening of the daylight, lowering of the temperature and humidity. Eaton [1924] suggested that temperature influenced growth and flower production of soyabean as did the daylength. Tincker [1928] observed by sowing *Phaseolus multiflorus* at different dates, that 'the temperature effect in June, July and August could hardly be such as to limit growth. In Sep-

tember and October temperature was undoubtedly a most important factor'. He found that with the lateness of sowing from May 9 to September 9, the plants became shorter, and the sowings at the end of August and September produced no fruits and ultimately became checked in growth. Tincker explains the latter condition as an effect of low temperature. In present investigation it was also found that in the December, January and March Sowings several plants died before reproduction. The percentages of the plants died before budding are 35 per cent, 45 per cent and 35 per cent, before the opening of flower are 45 per cent, 55 per cent and 55 per cent and before the fruiting age are 55 per cent, 65 per cent and 60 per cent in the 25 December, 24 January and 25 March sowings respectively of I. P. 28. These may be accounted for as due to very low minimum temperature in the first two and very high maximum temperature in the last sowing. The temperature, perhaps, also regulates the opening of the flower. Another external factor, which is not the least important, comes into prominence in this case. This factor is the entire absence of the rainfall. The 25 November and 25 December sowings are characterised by having the longer vegetative periods and they took 18 days from the initiation of flower buds to the opening of flowers. This retardation of the reproductive growth may be attributed to the low temperature and humidity, and the absence of rainfall.

The influence of rainfall is marked in the 15 August sowing of *Sona Mung* during the later days of the month of September (15 September to 1 October) the rainfall suddenly rose from 0·13 to 0·59. The vegetative growth was markedly enhanced in the 15 August sowing of *Sona Mung* during this period—the increase in the height (11·95), number of nodes (5·70), leaves (11·45) and branches (2·50) being the highest not merely amongst all the stages of the same sowing, but also among all the stages of all the sowings.

Mukherjee [1945] in an experiment on the effect of water supply to *Mung* (I. P. 28) plants, found that the growth increased and the flowering time hastened with an increase in water supply.

It may be said that the daily light period and temperature decreased with the lateness in sowing from 15 August to 29 October and the sum total effects were that the vegetative growth had clearly decreased with the lateness of sowing time during this period in both the varieties of the plant. But the flowering time seems to be influenced in the opposite manner in the two varieties. Experiments of photoperiodic treatment have shown that the flowering time was enhanced in *Sona Mung* and retarded in I. P. 28 with the increase in the length of the light period.

As the sowing time was delayed from 15 August to 29 October the vegetative period of I. P. 28 was lengthened from 34·8 to 49·4 days and that of *Sona Mung* was shortened from 65·5 to 27·0 days. The bud initiation was also delayed as the sowing of I. P. 28 was delayed from 26 October 1944 to 25 December 1944 after which it was enhanced from 60 to 51 days in the 25 March sowing. This may be co-related with the length of day and the temperature, both of which gradually decreased from August to January and increased from January onwards. The

rainfall was also of influence in this connection, as it was found in 1945 that an increase in the water supply induced earliness in the initiation of the reproductive phase in I. P. 28. It is, however, not possible to say which of the three factors was or were more dominating in this case without further researches in this line. All the more difficult is the question of correlating the cases of exception to the general trend in the case of the 14 September sowing in I. P. 28, in relation to its budding and fruiting period, the fruiting time of the 15 August sowing, and the flowering time of the 14 October sowing, to definite factor or factors; although it should be remembered that the differences in question are very slight in most of these cases, and that the data presented are the mean of readings of 20 plants in each case.

If the relative effects of 10-hour and 14-hour light treatments on the initiation of the reproductive phase in the two varieties are compared, it becomes clear that the shorter light period enhanced the flowering time and longer light period retarded it in I. P. 28, whereas in *Sona Mung* the longer light period enhanced the flowering time and shorter light period retarded it. The nature of the response to the different light periods is therefore reverse in the two varieties.

Tincker [1928] observed that ' seasonal length of day regulated the elongation of the stem in a similar manner to the artificially controlled day-light '. He found that ' short day ' caused *Phaseolus multiflorus* to remain as branched dwarfs and to flower earlier. The result tallies with the present investigation as regards dwarfness is concerned, but flowering time of one variety of *Mung* was reverse of the other, *Sona Muug* flowering earlier with short photoperiod and was associated with the least number of branches as opposed to Tincker's observations, and I. P. 28 behaves just in the reverse manner.

The photoperiodic response, as recorded by the differnces in the flowering time in relation to the differences in the light period, is more intense in *Sona Mung* than in I. P. 28. Further investigations with longer and shorter photoperiodic treatments are necessary for a clear understanding of the further details of the photoperiodic effects.

The photoperiodic results clearly show that the two varieties are entirely different as regards their optimum light requirement and *Sona Mung* requiring a lesser amount of daylight for early initiation of reproductive stage may be called a ' short day plant ', whereas the I. P. variety—requiring a greater amount of daily illumination—a ' long day plant ' in the same sense of the terms as applied originally by Garner and Allard [1920].

Similar fundamental differences in the photoperiodic response have also been recorded by Murneek [1936], viz., the ' Biloxi ' variety of soyabean—a short day crop—is considerably retarded in its development by the increase of daylength, whereas the ' Mandarin ' variety of the same crop shows little response to such a change and bloom simultaneously. Oakley and Westover [1921] distinguished

different varieties of Lucerne by treating them with the illumination for varying periods, and studying their respective responses.

Garner, Bacon and Allard [1924] found an increase in the length of the stem in the 'short day' plants and a decrease in the 'long day' ones when treated with long daily illumination. According to them, an increase in the active acidity of the plants, particularly in the growing point, is associated with the former, and a low level in the acidity with the latter case. Adams [1923] working on flax, wheat, sunflower and a few other plants interpreted that the plants exposed longest to the action of light attained the greatest height and flowered earlier. Tincker [1928] did not observe increased elongation in *Phaseolus multiflorus* treated with short day light. Redington [1929] found that Pisum, Vicia, etc., grew best in longer exposure to illumination.

The authors did not find increased elongation of the stem due to short photoperiod in any of the two varieties of *Mung*. This result partly tallies with that of Garner, Bacon and Allard, and fully with that of Tincker and Adams in that the height was the greatest in the plants treated with longer daily illumination.

In the treatments which prolonged the vegetative period, the ultimate height, number of nodes, leaves and branches were also much greater. This behaviour which was also found by Murneek was explained by him by stating that when blooming was retarded the organic substances elaborated were directed towards the formation of new leaves. Long day plants grown in shorter daylength would have greater vegetative growth, but due to reduction in the photosynthesis period there would be lesser accumulation of organic substances, which might be the cause for the lesser growth in the case of I. P. 28.

The pre-sowing low-temperature treatments of 10 days reported here seem to have no clear responses, though some earliness or lateness in the stages of budding, flowering and fruiting and some differences in the vegetative growth have been recorded. The response, though feeble, seems to be more evident in *Sona Mung*. It will however be useful to try longer periods of vernalization treatments, but an experiment on 45-day treatment has shown that these seeds failed to germinate.

Lastly, it is an important observation that the dates of the initiation of the reproductive phase for the six successive sowings of *Sona Mung* lie between 20 October and 25 November and in general, in the month of November—which can well be said to have the optimum external conditions for the reproductive phase of *Sona Mung*. In I. P. 28 this is not at all noticeable, the initiation of the reproductive phase taking place on widely separated days between 19 September and 17 December for the same set of sowings. The behaviour of *Sona Mung* in this respect can be said to be similar to the jute plants, ('short day' plants) where for widely separated dates of sowing (1 April to 30 June) the flowering takes place within the narrow period between the middle of August and the middle of September (in press.)

SUMMARY

For each treatment five pots with four plants each were used.

Two varieties of *Mung* (*Phaseolus aureus* Roxb.)—I. P. 28 and *Sona Mung*—were sown at intervals of 15 days from 15 August 1945 to 29 October 1945; there being six sowings. For I. P. 28 there were six sowings in addition at intervals of 30 days from 26 October 1944 to 25 March 1945.

Sown on 14 September 1945 the plants of both the varieties were subjected to 10-hour and 14-hour daily light treatment.

Sown on the same date one set of seeds was subjected to pre-sowing cold temperature treatment (2°C.—4°C.) for 10 days.

For sowings between 15 August to 29 October, the flowering time was reduced with the lateness of sowing in *Sona Mung*, but in I. P. 28 the flowering time was enhanced with the lateness of sowing.

For the same period the vegetative growth in both the variety decreased with the lateness of sowing.

For the sowing of I. P. 28 between 26 October 1944 to 25 March 1945, the flowering time tended to increase till the December sowing after which it tended to decrease till the March sowing. The vegetative growth however did not show any regularity in its trend of variation.

The relative influence of meteorological factors on growth and development of the palnts has been discussed.

The I. P. 28, variety behaved as a 'long day' plant and *Sona Mung* as a 'short day' plant, the nature of photoperiodic response is therefore reverse in the two varieties.

The response to pre-sowing low-temperature treatment (vernalization) of 10 days was not distinct and clear.

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EXPLANATION OF PLATES

PLATE II

FIG. 1. Sown on 15 August, 1945.

Photograph taken on 14 October 1945.

Age of the plants—60 days.

Experiment—Time of Sowing.

Showing that at the time when *Sona Mung* (3) was about to flower, the I. P. 28 (3A) variety was at the end of its life.

(*Sona Mung* produced flower buds in 65·50 days and Mung I. P. 28 in 34·80 days).

FIG. 2. Sown on 29 September, 1945.

Photograph taken on 29 October, 1945.

Age of the plants—30 days.

Experiment—Time of Sowing.

Showing that *Sona Mung* (103) and I. P. 28 (56) variety were almost similar in their growth and development, though greater number of leaves can be noticed in *Sona Mung*

(*Sona Mung* produce flower buds in 34·85 days and *Mung* I. P. 28 in 39·70 days).

Fig. 1.

Fig 2.

FIG. 3.

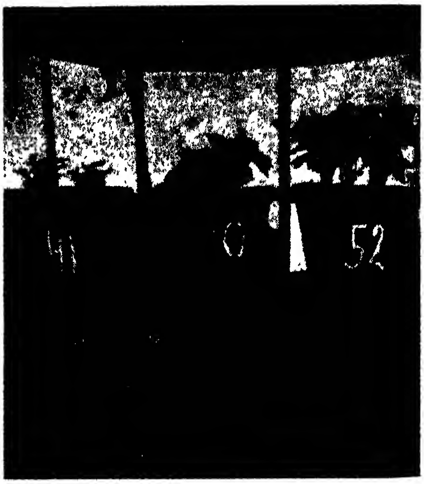

FIG. 4.

FIG 5.

PLATE III

FIG. 3. Sown on 14 September, 1945.

Photograph taken on 29 October, 1945.

Age of the plants—45 days.

Experiment—Photoperiodism.

Showing that the vegetative growth in *Sona Mung* was the highest in the 14-hour illuminated plants (46), next higher in the controls (12) and the lowest in the 10-hour illuminated plants (39).

(The 14-hour treated plants produced flower buds in 55·25 days, the controls in 46·10 days, and the 10-hour treated plants in 44·10 days).

FIG. 4. Sown on 14 September, 1945.

Photograph taken on 29 October, 1945.

Age of the plants—45 days.

Experiment—Photoperiodism

Showing that the vegetative growth in *I. P. 28* was the highest in the 14-hour illuminated plants (52), next higher in the controls (20) and the lowest in the 10-hour illuminated plants (41).

(The 14-hour treated plants produced flower buds in 40·65 days, the controls in 40·45 days and the 10-hour treated plants in 46·87 days).

FIG. 5. Sown on 14 September, 1945.

Photograph taken on 6 November, 1945.

Age of the plants—53 days.

Experiment—Photoperiodism Vernalization.

Showing that the vegetative growth in *I. P. 28* was the highest in the 14-hour illuminated plants (51) next higher in the 10-day vernalized one (31), next higher in the controls (16) and the lowest in the 10-hour illuminated plants (45).

(The plants of the Pot. No. 31 seem to be of the same height as those of the Pot No. 51. But this is due to the level of the pots being not even).

PLATE IV

FIG. 6. Sown on 14 September, 1945.

Photograph taken on 21 November, 1945.

Age of the plants—68 days.

Experiment—Photoperiodism and Vernalization.

Showing that the vegetative growth in *Sona Mung* was the highest in the 14-hour illuminated plants (48), next higher in the controls (13), the lowest being the 10-hour illuminated plants (36) and the 10-day vernalized ones (26). The two latter are seen to be at the last stage of their life. Plants of Pot No. 48 are seen to be very strong (These plants produced fruits after 73·50 days, whereas the others produced fruits after 53·10 to 55·47 days).

FIG. 7. Sown on 14 September, 1945.

Photograph taken on 7 December, 1945.

Age of the plants—84 days.

Experiment—Photoperiodism and Vernalization.

Showing that *Sona Mung* illuminated 14 hours daily (47) was healthy and strong, and produced fruits when the controls (12), the 10-hour illuminated plants (38), and the 10-day vernalized ones (27) all have died.

FIG. 6.

STUDIES IN NITROGEN AND CARBOHYDRATE METABOLISM OF SUGARCANE

By H. P. Varma, M.Sc., A.H.B.T.I., Senior Physiological Assistant, Main Sugarcane Research Station, Shahjahanpur

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THESE studies were started in 1943 with the main object of elucidating the metabolic changes going on in sugarcane under various conditions of growth. The results of an investigation on the growth of the sugarcane as affected by seasonal variations at Shahjahanpur have already been published by Mathur [1941]. A study of the metabolic changes in the cane plant with respect to nitrogen and sugars has not, however, so far been attempted by research workers in India; and to fill up this important gap in the knowledge, the present investigation was undertaken.

A brief review of the literature on the more important work on nitrogen and carbohydrate metabolism is given below.

Sapoznikow [1895] found that there was increase of proteins with increase of carbohydrates in leaf. Chibnall [1922] working on runner beans found that nitrate and mono-amino nitrogen vary directly with protein, indicating that they may be connected with protein synthesis. Phillis and Mason [1947] have shown that proteins in leaf increase as crystalloid nitrogen increases upto a point, and that subsequently an increase of crystalloid nitrogen is accompanied by a decrease in protein nitrogen. Sure and Tottingham [1911] working on peas showed that amino acids are more in evidence during early stages and disappear later. Richard and Templeman [1936] showed that leaves are high in nitrogen when young, but total nitrogen goes down with the age of the leaf because nitrogen travels to the younger parts. Ruhland and Wolf [1936] working on sugarcane leaf found that in the earliest leaves sugars tend to diminish with advancing age of the leaves; but that in the later leaves an opposite effect is perceived. Das [1936] also working on sugarcane found that under conditions of rapid vegetative growth sucrose content is low and reducing sugars are high. In sugarcane the accumulation of sucrose is a node to node process and stops when the leaf attached to the node falls off.

The present study embodies the following aspects:

1. The effect of age on the metabolism of sugarcane.
2. The effect of yellowing disease on sugarcane metabolism.
3. Preliminary observation on the effect of pyrilla infestation on the metabolic processes.

Analytical methods

Prior to the commencement of these investigations modern methods of micro-chemical analysis were adapted to suit the specific requirements.

Total nitrogen was determined by the usual Micro-Kjehldahl method (1).

Crystalloid nitrogen was determined by precipitating proteins from the water extract of the material with trichlor-acetic acid; 5 c.c. of the filterate was treated with

1 c.c. of 50 per cent sulphuric acid and a pinch of reduced iron. Nitrogen content of this portion was determined by Micro-Kjehldahl method.

Protein nitrogen was expressed as the difference between the total and crystalloid N.

Amino nitrogen was determined by Brown's (2) modification of Sorensen's formal titration method using Phenol red as indicator.

Amide nitrogen was determined by B. Wolf's method (3) of aerating ammonia-free air through N/100 boric acid solution.

Sugars (total, sucrose and reducing) were determined by C. S. Hanes' modification (4) of Hagedorn and Jenson's (5) method for determination of larger quantities of reducing sugars.

Sampling and preservation

Material from different experiments was sampled at random on specific dates. When taking samples of leaves, three first fully emerged leaves were taken arbitrarily from each row of a plot excluding the border rows. For the whole plant sample, only two plants were dug out, one each from any two rows of a plot excluding the border rows. In all cases samples were taken in the morning. The samples were killed by keeping them within half-an hour of their collection in an electric oven maintained at a temperature of 100°F.—110°F. for three to four hours. This period was sufficient to kill the enzymes of the tissues. They were then thoroughly dried at 90°C. to 95°C., powdered and preserved in packets for future analysis.

Observations

1. *Study of the effect of age on sugarcane metabolism*

For these studies variety Co. 313 was selected. Monthly samples of the whole plant were taken from a plot which did not receive any additional manure excepting a basal dressing of *sanai* (*Crotolaria juncea*) green manure. Leaf, leaf-sheath and stem were analyzed separately for nitrogen and carbohydrate fractions. The analytical results for the leaf as averaged for three consecutive seasons are detailed in Table I.

TABLE I

Nitrogen and carbohydrate fractions in the leaf of Co. 313 (average of three years)
(per cent dry weight)

Items	April	May	June	July	August	September	October	November	December	January	February
Total N	1·5760	1·7440	1·7147	1·4627	1·1017	1·0460	·9165	·8000	·6505	·6545	7410
Crystalloid N	·3054	·2745	·2737	·2593	·2312	·2959	·2250	2279	·2142	·2505	·2042
Protein N	1·2706	1·4695	1·4410	1·2034	·8705	·7501	·6915	·6621	·4363	·4040	·5368
Amino N	·0417	·0252	·0268	·0236	·0135	·0215	·0254	·0144	·0119	·0228	·0180
Amide N	·0800	·0250	·0611	0484	·0501	·0761	·0695	0483	·0541	·0846	0876
Total sugars	3·83	6·16	4·59	5·88	4·59	5·28	8·05	5·04	8·06	6·96	7·24
Invert sugars	1·88	2·37	1·43	1·21	1·73	1·83	1·97	1·65	2·82	2·31	2·02
Sucrose	1·95	3·79	3·16	4·17	2·86	3·45	6·08	3·39	5·24	4·65	5·22
Crystalloid per cent of *total* N	19·37	15·74	15·96	17·72	20·98	28·29	24·56	25·61	32·04	38·27	27·55

Leaf.—It will be seen from the above table that *total nitrogen* is high upto June which is the period of high metabolic activity in the plant. It begins to fall after this month and the decline is gradually maintained till harvest. The fall may be attributed to age effect and is quite independent of weather conditions. *Protein N* follows the same trend as the *total* N. It appears that the fall of total N is mainly due to decreased protein synthesis as the plant ages. *Crystalloid N* which represents the soluble N fraction shows slight proportionate increase when expressed as percentage of *total* N. This increase may partly be due to increased hydrolysis of proteins, resulting in the accumulation of lower soluble nitrogenous compounds.

Amino N is high in April, but gradually falls off in the following months, slightly rising again towards the end period. *Amide N* is high in April but falls upto August after which it rises again slightly and falls in November and December, with a slight rise in the end. The behaviour of these two fractions is more or less erratic, but nevertheless high values in the beginning and towards the end may indicate that they first synthesise into protein building material and form protein hydrolysis products at the end. *Total sugars* are high in the beginning but remain more or less constant till November after which there is a slight rise which is maintained till the end. The behaviour of invert sugars and sucrose very much resembles that of the *total sugars* viz., high in the beginning and then showing a slight rise again at the end.

The data for the nitrogen and carbohydrate fractions in leaf-sheath are shown in Table II.

TABLE II

Nitrogen and carbohydrate fraction in the leaf-sheath of Co. 313 (average of three years) (per cent dry weight)

Items	April	May	June	July	August	September	October	November	December	January	February
Total N	1·0860	·9400	1·2860	·7765	·4965	·4740	·4260	·4335	·4045	·3690	·3120
Crystalloid N	·3741	·3502	·3006	·2533	·1648	·1804	·1859	·1898	·1655	·1464	·1437
Protein N	·7119	·5898	·9854	·5232	·3316	·2936	·2400	·2437	·2389	·2226	·1683
Amino N	·0606	·0404	·0390	·0249	·0092	·0082	·0123	·0153	·0207	·0130	·0076
Amide N	·0593	·0323	·0601	·0342	·0498	·0234	·0395	·0458	·0428	·0487	·0585
Total sugars	4·36	4·85	11·22	9·93	7·39	5·92	7·20	11·76	21·39	13·01	9·58
Invert sugars	3·76	·133	4·88	3 50	3·85	3·82	3·60	3·85	4·17	4·54	3·30
Sucrose	·60	3·52	6·34	6·44	3·53	2·10	3·60	·7·91	17·22	8·47	6·28

Leaf-sheath.—From Table II which shows averages for leaf-sheath, it will be seen that the behaviour of nitrogen fractions is very much the same as in leaf, the only difference being that the absolute values of total and protein N are less in this component of the plant. The trend of total sugars is also similar to that in the leaf; but the absolute values are much higher. Invert sugars and sucrose follow the trend of *total sugars*. The data for nitrogen and carbohydrate fractions in stem are shown in Table III.

TABLE III

Nitrogen and carbohydrate fraction in the stem of Co. 313 (average of three years) (per cent dry weight)

Items	April	May	June	July	August	September	October	November	December	January	February
Total N	..	1·2740	1·2590	·9960	·4360	·2890	·2970	·2380	·2740	·2810	·1670
Crystalloid N	..	·6579	·6171	·3923	·2060	·1705	·2035	·1710	·2116	·2345	·1270
Protein N	..	·6161	·6419	·6037	·2300	·1185	·0935	·0670	·0624	·0465	·0400
Amino N	..	·1737	·1319	·0428	·0136	·0107	·0170	·0229	·0323	·0371	·0133
Amide N	..	·1224	·1312	·0647	·0489	·0411	·0624	·0501	·0658	·0829	·1002
Total sugars	..	3·56	9·13	14·93	15·99	26·39	29·25	28·90	39·38	4·793	32·15
Invert sugars	..	1·03	2·15	5·72	12·05	11·24	8·29	5·12	3·79	6·86	2·27
Sucrose	..	2·53	6·98	9·21	13·94	14·61	20·79	23·78	35·59	27·93	29·88
Crystalloid per cent of *total* N	..	51·64	49·03	39·39	47·25	58·98	68·52	71·85	77·21	83·45	76·05

Stem.—From the above it will be seen that the trend of total N and protein N is the same as in the leaf and leaf-sheath viz., high in the early stages and decreasing subsequently. Their absolute values are, however, very low. Crystalloid N increases with age and its values when expressed as percentage of *total* N are much higher than either in the leaf or leaf-sheath. It is interesting to note that in the stem there is preponderance of crystalloid N. This is evidently due to the nitrogen being stored in the soluble form in the stem which is a storage organ. Unlike the green leaf or leaf-sheath, amino and amide N are fairly high in the stem during the early stages. This period synchronises with that of vigorous growth and rapid protein synthesis, *i.e.*, the tillering period of the plant. After this period both these fractions show a fall upto September, subsequently showing again a slight rise. This rise is not apparently due to active protein synthesis, but may partly be due to the accumulation of protein degradation products at the end of the plant life. It is clearly established from the above data that proteins are gradually disappearing from the stem and are being replaced by soluble nitrogen fractions which are comprised mostly of amino and amide N.

Total sugars, as calculated on dry weight, go on increasing from the early stages to the harvest. It will be seen that nitrogen and carbohydrate content in the stem

are inversely correlated, *i.e.*, with the fall of nitrogen content the carbohydrate content increases. Invert sugars increase upto September and then begin to fall. From this month onward the increase of sucrose is very rapid. Sucrose very much follows the course of *total sugars*.

2. *Study of the effect of yellowing in sugarcane leaves*

For the last two or three years yellowing of leaves has been observed in the crop during the months of August and September. It has been definitely established that this phenomenon does not occur due to the incidence of any fungus disease or pest. In order to understand the metabolic differences between the healthy and yellow plants, a sample each of healthy and yellow plant was analyzed for nitrogen and carbohydrate contents. Leaf and stem of both the types were analyzed.

From the Table IV which gives averages of three years for leaf and two years for stem it will be seen that both total and protein N are more in the leaf of healthy than in that of the yellow plant, showing thereby that yellowing reduces protoplasmic content in green parts. This is further corroborated by the preponderance of amino and amide N in yellow over healthy leaves which indicates that yellow leaves abound in protein degradation products. The same is true in the case of stem also. Total and protein N are more in the healthy stem and the protein degradation products such as amino and amide N are more in the stem of yellow plant.

TABLE IV

Nitrogen and carbohydrate fractions in the leaf and stem of healthy and yellow plants in the month of September (per cent dry weight)

Items	Average of 3 years		Average of 2 years	
	Healthy leaf	Yellow leaf	Healthy stem	Yellow stem
Total N	·9293	·7644	·3620	·3120
Crystalloid N	·2412	·1993	·2188	·2041
Protein N	·6881	·5651	·1381	·1082
Amino N	·0198	·0240	·0100	·0125
Amide N	·0385	·0726	·0246	·0786
Total sugars	5·99	7·91	25·02	33·07
Invert sugars	1·67	2·69	9·00	14·27
Sucrose	4·32	8·55	16·01	18·80
Sucrose per cent of *total sugars*	..	..	64·00	56·85

Total sugars are on the other hand more in the yellow plant both in the leaf and the stem. It cannot, however, indicate increased photosynthetic activity because from the analysis of nitrogen fractions it has been seen that yellowing causes destruction of living protoplasmic matter. The increase of total sugars may be due to two reasons.

1. Translocation machine in the leaf is disturbed. This is borne out by the fact that total sugars in yellow leaf are nearly double of that in the green leaf. In the stem the difference is not so marked.

2. Yellow plants react to the adverse circumstances and perhaps tend to ripen early, and this increase may be due to early ripening.

It will be interesting to note that although *total sugars* and sucrose are more in the stem of yellow than in the green plant, sucrose expressed as percentage of *total sugar* is less in the case of the former. Invert sugars are also more in the yellow plant. It may indicate partial cessation of the process of elaboration from lower to higher sugars due to yellowing.

3. *Preliminary observation on the effect of pyrilla infestation on the metabolism of sugarcane*

A sample each of pyrilla free and infested leaves was taken from a field heavily affected by pyrilla at Gorakhpur Farm. As usual the samples were analyzed for nitrogen and carbohydrate fraction to understand differences, if any, between the metabolism of the two types of leaves. It is intended to continue this study whenever the pyrilla attack is severe again.

TABLE V

Nitrogen and carbohydrate contents in pyrilla free and infested leaves, August 1945 (per cent dry weight)

—	Pyrilla free leaves	Pyrilla infested leaves
Total N	1·0550	·9000
Crystalloid N	·1964	·2171
Protein N	·8586	·6829
Amino N	·0203	·0209
Amide N	·1108	·0582
Total sugars	5·43	4·67
Invert sugars	1·15	2·21
Sucrose	4·28	2·46

Table V shows the different fractions in the two types of leaves. A comparison of the two will show very interesting results. It will be seen that both total and protein N are more in the healthy than in the pyrilla infested leaves indicating thereby that in some way pyrilla partly inhibits protein formation. It is further supported by the presence of more crystalloid N in pyrilla infested leaves than in the healthy ones. It appears that lower nitrogenous compounds are not fully utilized in elaboration of proteins and therefore accumulate in quantity. Although amino N is nearly equal in the two, amide N is more in the healthy than in the yellow leaf. The role of amide N is not very clear in this case.

Total sugars and sucrose are also more in the healthy leaves than in the infested leaves. Pyrilla, therefore, not only partly inhibits protein elaboration process but also appears to destroy sugars in leaf. Presence of high glucose values in the infested leaves further supports the view that although the basal material (reducing sugars) for elaboration of higher sugars is there, pyrilla reduces part of the higher sugars so formed by sucking it.

Summary

The following tendencies seem to be clearly indicated from the above experiments :

1. There is more of *total nitrogen* in leaf, followed by leaf-sheath and stem.
2. *Total nitrogen* goes down with age in all the parts.
3. During the later part of the plant life, there is greater accumulation of soluble nitrogen (crystalloids).
4. In the stem soluble nitrogen predominates. In the later part of the plant life *total nitrogen* in the stem is mostly in the form of crystalloids.
5. Amide nitrogen content is always higher than amino nitrogen. This is specially true when the plant grows old, showing thereby that amide nitrogen is the main hydrolysis product of proteins in sugarcane.
6. *Total sugars* in leaves go up with age.
7. Yellowing diminishes protein content and increases *total sugar* content in leaf and stem.
8. Pyrilla attack diminishes both nitrogen and sucrose content in leaf.

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AGRICULTURAL PROBLEMS OF THE TUNGABHADRA IRRIGATION PROJECT, MADRAS PRESIDENCY

By M. Chinnaswamy Naidu, L.Ag., Deputy Director of Agriculture, Tungabhadra Project, Bellary

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THE four districts of Bellary, Anantapur, Kurnool and Cuddapah, comprising the Ceded Districts of the Madras Presidency, are subject to frequent famines of varying magnitude, due to their peculiar geographical situation in the South Indian Peninsula. The rains received are erratic both in incidence and magnitude and it has been the experience of the tract that out of 70 years on record, 34 years had suffered from deficiency of rainfall. The tract receives on an average a rainfall of 22·89 inches. The most satisfactory solution to avoid famine and ensure good crop-growth in this zone is to harness the water from the Tungabhadra which forms the boundary between Madras and Bombay in one stage and Madras and Hyderabad at another stage of its course, and utilise the water for irrigation. On the Madras side, nearly 0·26 lakhs of acres are already under wet cultivation where paddy, sugarcane etc., are cultivated for the past several years. The Government of Madras in consultation and in co-operation with the Hyderabad State Government have started constructing a dam across the Tungabhadra near Hospet (Bellary District). The reservoir is estimated to supply about 50 thousand cubic feet of water per year to each territory.

The scheme is intended to benefit a large extent of the tract by providing irrigation to crops that are normally cultivated under rainfed conditions. The tract receives both south-west and north-east monsoons and during the former period termed locally as *mungari* (*kharif*) crops like *jonna* (Sorghum), *korra* (*Setaria italica*), cotton, groundnut and pulses are grown on the light black and red soils. In the north-east monsoon period termed locally as *hingari* (*rabi*), cotton, *jonna*, Bengal-gram, safflower and wheat are grown on the heavy black soils. About 80 per cent of the project with a commanded area of 2·5 lakhs of acres in parts of Bellary and Kurnool Districts, consists of black soils. It is proposed to give light irrigation of about two inches depth, once a fortnight, for a period of four months, either in *hingari* or *mungari* seasons. Provision will also be made for wet lands 'garden lands' and orchards in the project area. The distribution of cropping will be as follows :

Under 'dry-crop irrigation'	192,000 acres (4 months supply)
Under 'wet lands' and 'orchards'	51,000 acres (8 months & perennial)
Under 'garden lands'	7,000 acres (8 months)
Total	250,000 acres

The success of irrigating black soil has often been questioned. It is often asked why very little use is made of the water from the Cuddapah-Kurnool Canal which runs through the black soil tracts. The failure of the Nira Valley Project in the Bombay-Deccan, where alkalinity developed in the black soils, as a result

of irrigation is cited as an example. The possibility of development of alkalinity in the project area is examined during the soil survey conducted in 1934-35 by the Agricultural Department with special reference to sub soil and bed rock. The conclusion arrived at were, that the soils could be successfully irrigated without developing alkalinity provided (*a*) proper drainage is assured and (*b*) a system of distribution is devised to prevent indiscriminate use of water. Another great advantage noticed was that the water of the Tungabhadra contained a very low percentage of salt (·007 to ·027 per cent). It was found quite safe to be used for irrigation.

TRIALS CONDUCTED ON THE AGRICULTURAL RESEARCH STATION, SIRUGUPPA

Nearly 80 per cent of the tract consists of black-soil and it was classified by Ramiah [1937] into four groups, viz., (i) deep soils (more than three feet) with gypsum ; (ii) deep soils without gypsum ; (iii) shallow soils (less than three feet) with gypsum and (iv) shallow soils without gypsum. The soils were found to rest on a layer of white *kankar* (disintegrated granite) locally known as *garasu*. The black soils of the tract are rich in clay and have high water holding capacity with low permeability. The percentage of salts is low in the top three feet in concentrations not injuries to crop growth. They are chiefly composed of gypsum, sodium choloride and sodium sulphate. Shallow soils form about 20 per cent of the project area and are mostly situated near water courses termed locally as '*vanka*'. The main object of starting the Agricultural Reasearch Station, at Siruguppa was (*a*) to test the adverse effect if any, in irrigating the black soils and (*b*) to fiz suitable crops for raising in different seasons. The chemical and agronomic studies pursued are dealt below.

Chemical studies

The black soils of the project area have low salt content in the top three feet of soil [Ramiah, 1937]. It was feared that when the application of water is restricted only to crop growth period and left unirrigated in summer, an accumuation of salts in the profile, especially in the upper layers may be felt in course of years To test whether.such increase in salt content does take place in the top profile investigations were carried in deep and shallow black soils, receiving light or copious irrigation. Since the data obtained from the samples drawn prior to irrigation, after harvest of the crop, and in summer, did not show any appreciable difference during the several years examined, only summer samples were considered in the present study. The data of the samples when the land was brought under irrigation and those collected after several years of irrigation were compared. In the case of deep black soils, data was also collected from three irrigation treatments and compared with the control (unirrigated). In this study the soils were not ploughed or manured throughout the experimental period. Cotton and *jonna* were grown in rotation during the *hingari* season. In the case of shallow soils ploughing and manuring were done every year but irrigation was restricted to once a fortnight. In addition, samples were examined from profiles with gypsum and without gypsum. In the case of shallow soils receiving copious irrigation (wet-lands) heavy manuring

and ploughing was done every year. Paddy and sugar-cane were grown in these blocks. The percentages of soluble salts estimated at different depths in the various cases mentioned above are given in Table I.

TABLE I

Showing the percentage of total soluble salts on air-dry basis in different depths of different kinds of black soils receiving varying intensities of irrigation

Serial number	Treatment	Sampling date	Depth of soil: First foot	Second foot	Third foot	Fourth foot	Fifth foot
1	No irrigation	1939	0·08	0·09	0·13	0 59	0·71
		1944	0·07	0·09	0 12	0·18	0 64
2	Restricted irrigation in deep soils receiving no manure						
	(a) Two inches once in 15 days	1939	0 08	0·09	0 11	0·14	0 33
		1944	0·07	0·10	0·10	0·13	0·23
	(b) Three inches once in 15 days	1939	0·08	0·09	0·10	0·15	0·61
		1944	0·08	0 09	0 11	0·14	0·30
	(c) Three inches once in 30 days	1939	0 08	0 10	0·12	0 22	0·69
		1944	0·07	0 09	0 10	0 42	0 22
3	Restricted irrigation in shallow soils manured every year. (2½ tons of farm yard manure + 50 N as groundnut cake)						
	(a) Non-gypseous	1943	0·08	0·09	0·42	..	..
		1946	0·09	0·12	0·20	..	..
	(b) Gypseous	1943	0·12	0·20	0 44	..	..
		1946	0·07	0·13	0 28	..	..
4	Copious irrigation in shallow soils heavily manured every year. (6 tons of green leaf + 40 lb. of N. as groundnut cake and ammonium sulphate + 20 lb. of P_2O_5 as bone meal)						
	(Wet lands)	1940	0 10	0 50	1 11	..	..
		1945	0·10	0·21	0·17	..	..

It is seen that in no case an increase in percentage of salts in course of years as compared with the respective initial samples is felt. On the other hand, in the case of gypseous soils and in samples drawn from the lower layers which had higher salt content, a fall in values is noted.

Agronomic studies

The main lines of investigations made under this item were studies (i) on the effect of mere irrigation, (ii) on the effect of early and late sowing, (iii) manurial trials, (iv) trial of crops and varieties suitable for the black soils under irrigation and (v) on the duty of water.

(I) *Studies on the effect of mere irrigation.* The rainfed crops are not normally manured. It was therefore planned to know the effect of mere irrigation on these crops. No appreciable increase in yield was obtained in any of the crops as seen in Table II.

Table II

Yield per acre in pounds

Serial number	Treatment	*Jonna* (local yellow) *Mungari* season						*Korra* (local) *Mungari* season			Cotton (Hagari.1.) (*G. herbaceum*) *Hingari* season		
		1939-40		1940-41		Mean		1939-40	1940-41	Mean	1938-39	1939-40	Mean
		Grain	Straw	Grain	Straw	Grain	Straw	Grain yield only			Seed—cotton yield		
1	Rainfed	497	1153	304	808	401	981	363	498	431	340	425	383
2	Irrigated	682	1737	218	1037	450	1387	404	242	323	330	403	367
	C. D. at 5 per cent level	Not significant	Not significant	Not significant	229	..	..	Not significant	Not significant	..	Not significant	Not significant	..

(II) *Studies on the effect of early and late sowing.* In this trial also no manuring was done to the crops, but they were irrigated. The results of the investigations are given in Table III.

Table III

Showing the results of the time of sowing experiment conducted with various crops on the Agricultural Research Station, Siruguppa

Serial number	Treatment	*Jonna* (local) *Mungari* season			*Korra* (local) *Mungari* season			Groundnut (A.H. 25) *Mungari* season			Cotton (Hagari.1.) (*G. herbaceum*) *Hingari* season		
		1939-40	1940-41	Mean	1938-39	1939-40	Mean	1938-39	1939-40	Mean	1938-39	1939-40	Mean
					Grain yield only			Pod yield only			Seed—cotton yield		
1	Early	$\frac{682}{1737}$	$\frac{218}{1037}$	$\frac{450}{1387}$	616	404	510	1022	1732	1377	330	403	367
2	Late	$\frac{221}{2771}$	$\frac{167}{1374}$	$\frac{194}{2073}$	195	274	235	632	1051	842	325	237	281
	C. D. at 5 per cent level	Not significant	Not significant	..	..	..	..	..	..	..	..	..	..
		Not significant	80	..	283	Not significant	..	283	543	..	Not significant	Not significant	..

N.B.—In the case of *Jonna* numerator denotes grain yield and denominator straw yield

It is seen that though the yields of the crops are poor, the beneficial effect of early sowing is seen in all cases. In another set of experiments conducted with M.A.II cotton (*G. hirsutum*), at a later date in the *hingari* season of 1946-47, where the crop was manured at 80 N-level in the form of groundnut cake and 30-N and 40 P_2O_5 in the form of ammonium phosphate, the following results were obtained :—

YIELD OF SEED COTTON PER ACRE IN LB.

Time of planting

1 August	15 August	1 September	15 September	C. D. at 5 per cent level
1193	1302	810	215	249

Conclusion. It is seen that the yields of cotton sown in the month of August are definitely superior to those sown in September.

From the above investigations it may be concluded that mere irrigation of black soils will not be helpful to improve the yields of crops and other factors, like 'time of sowing,' manuring, etc., will have to be considered.

(III) *Manurial trials.* Investigations were conducted on irrigated H.A. 11 cotton, during three *hingari* seasons (1942-43, 1943-44 and 1944-45), with three nitrogen levels, viz., O N, 40 N and 80 N, in suitably replicated randomised blocks- Nitrogen was applied in the form of green manure, farm yard manure and groundnut cake. The results are given in Table IV. For the sake of brevity, only the effect of nitrogen levels is considered in the present paper.

TABLE IV

Manurial experiments

Main yield of kapas *per acre in pounds*

Variety H.A. 11 Cotton

——	1942-43	1943-44	1944-45	Mean
1. No manure	483	261	127	290
2. 40 N	672	531	344	516
3. 80 N	738	766	511	672
C. D. at 5 per cent level	73	45	53	..
Conclusions	$\overline{3, 2}$, 1	3, 2, 1	3, 2, 1	

It is seen that manured plots give higher yield than unmanured plots and that 80 N level is superior to 40 N level from the point of yield.

Investigations conducted in 1946-47 with *jonna* and cotton gave the following results with different levels of nitrogen and phosphates :—

(*a*) 'JONNA'

Yield per acre in lb.

Serial number	Manurial doses	Variety	Grain	Straw
1	0 N	A.S. 7437	913	5900
2	30 N	,,	1654	6974
3	60 N	,,	2244	7106
	C. D. at 5 per cent level	..	460	1196

Conclusions :

Grain 3, 2, 1
Straw 3, 2, 1

(*b*) 'JONNA'

Yield per acre in lb.

(Variety A.S. 2095)

Serial number	Manurial doses	Grain	Straw
1	30 N and 20 P_2O_5	2802	9231
2	30 ,, 40 ,,	2978	9972
3	60 ,, 20 ,,	3242	9670
4	60 ,, 40 ,,	3488	10907
5	90 ,, 20 ,,	3434	10357
6	90 ,, 40 ,,	3654	10687
	C. D. at 5 per cent level	110	225

Conclusions :

Grain 6, 4, 5, 3, 2, 1
Straw 4, 6, 5, 2, 3, 1
N applied in the form of groundnut cake and 'ammophos'
P_2O_5 ,, ,, ,, ,, ,, ammophos only

American Cotton

(Variety H.A. 11)

Serial number	Manurial doses	*Kapas* (seed cotton)
		Yields per acre in lb.
1	60 N & 30 P_2O_5	1529
2	60 „ 60 „	1772
3	80 „ 30 „	1675
4	90 „ 60 „	1723
5	120 „ 30 „	1796
6	120 „ 60 „	1893
	C. D. at 5 per cent level	111

Conclusions:

6, 5, 2, 4, 3, 1

N applied in the form of groundnut cake and 'ammophos'

P_2O_5 „ „ „ „ „ 'ammophos' only

In both the crops response of yield with increased doses of manures is seen.

(IV) *Trial of crops and varieties suitable for the black soil under irrigation.* Since 1943 a number of crops were tried under irrigation both in the *mungari* and *hingari* seasons. The details are furnished in Table V.

TABLE V

Showing crops raised in large scale plots at the Agricultural Research Station, Siruguppa on black soils with their yields, economics, etc.

Successful crop	Suitable variety	Growing season		Yield per acre in pounds		Cost of cultivation per acre including land taxes and water rates	Net profit per acre
		From	To	Grain	Straw		
						Rs.	Rs.
American cotton .	H.A. 11	September	March	767 (*kapas*)	..	77	73
Jonna .	A.S. 2095	June	September	1,172	4,516	59	83
Korra .	K. 132	June	September	911	1,521	59	33
Groundnut .	Local bunch	June	September	802 (pods)	..	93	33
Wheat .	Local	October	January	1,026	..	84	83

TABLE V—*contd.*

Showing crops raised in large scale plots at the Agricultural Research Station Siruguppa on black soils irrigation with their yields, economics, etc.—concld.

Successful crop	Suitable varity	Growing season		Yeild per acre in pounc		Cost of cultivation per acre including hand taxes pnd water rates	Net profit per acre
		From	To	Grain	Straw		
Maize	Yellow (Coimbatore)	June October	September January	1,000	3,500		63
Red gram	2232	June	February	500	..	as a mixture with crown *orra* and groundnut K	7 7
Ragi	E. C. 393	June	October	1,704	4,323	87	82
Onion	Dhulia	October	January	10,000	..	157	113
Chillies	Guntur 396	June	December	808 (dry fruits)	..	107	193
	Adoni	September	March	200 (dry fruits)			
Paddy	G.E.B. 24	July	November	2,701	4,570	130	14[illegible]
Sugarcane	Co. 419	February	January	27 (tons of cane)	..	412	433

It is seen that in addition to the rainfed crops of the tract other new crops like, wheat, *ragi*, maize could be raised successfully in the project area.

Cultural trials. In the Tungabhadra Project, it is proposed to supply water once fortnight for a period of four months in the year to facilitate *mungari* and *hingari* cropping. Water for the *mungari* season will be supplied from June to the end of September and for the *hingari* season from October to the end of January. The cultural trials conducted indicate the possibility of raising crops on the black soils both in the *mungari* and *hingari* seasons. The crops found suitable for the *mungari* season are *jonna*, *korra*, *ragi*, chillies, maize and groundnut and for the *hingari* season, cotton, wheat, maize, and chillies. In the above system cotton in the *mungari* and *jonna* in the *hingari* season could be grown successfully. The cultivators have to loss one of the above two important crops. A trial was made to rotate the cropping by treating the same land as *mungari* in one year and as *hingari* in the following year. The chief defect noticed in this method was that there was a long gap of about eleven months when a land cropped in the *mungari* season was next cultivated only in the *hingari* season. The land was unnecessarily left fallow for a considerable period. When the process was reversed there was a very short gap of only two months by cultivating the land in *mungari* season and cultivating it again in the *hingari* season. This system does not allow sufficient time for the various operations of preparatory cultivation.

A trial was made to investigate the possibilities of growing two crops in the same land in one year by supplying water for eight months. It was found that if water is supplied for eight months it is possible to raise in proper season and get remunerative yields. Either before or after harvest of the main crops, one can raise sunn hemp in June and plough it in August, and the cotton can be sown in September. Similarly after sowing *jonna* in July and harvesting the same in October, one can raise Bengal-gram crop or a green manure crop and plough it in by end of January.

Wet land cultivation is already in existence in the project area. In Siruguppa village, nearly, 3,000 acres are under cultivation with crops like sugarcane and paddy. Paddy and sugarcane were tried on the station. In the case of paddy, strain G. E. B. 24 and in sugarcane Co. 419 were grown. The agronomic trials on paddy were confined to growing (1) single crop and (2) double crop. In the case of single crop, planting was done in July and the crop was harvested by the middle of December, while in the case of double crop where two short duration varieties were tried, viz., A.D.T. 3 and Co. 8 the planting of first crop was done in June and harvested by end of September and the second crop was planted by the end of October and harvested by end of January. Observations recorded that in the case of double crop paddy the first year's response was good, but in later years, the yield of both the crops went down considerably as seen below.

DOUBLE CROP PADDY TRIALS

Yield per acre in lb.

	1942-43		1943-44		1944-45	
	Grain	Straw	Grain	Straw	Grain	Straw
First crop (A.D.T. 3)	3039	3939	2760	2613	1323	2116
Second crop (Co. 8)	2174	2745	1623	2549	Failed	

In rotation trials sugarcane and paddy were cultivated in alternate years. Paddy gave an average yield of 2,563 pounds of grain and 4,152 pounds of straw, and sugarcane 26 tons of cane.

(V) *Studies on the duty of water.* The duty of water for irrigating crops was calculated by the following formula :

$$\text{Duty of water } \frac{(a \times b \times c)}{d+e}$$

Where
'a' is period of crop growth in days.
'b' no. of hours, water was flowing daily to irrigate the crop during the growing period.
'c' area of the field irrigated.
'd' total acre inches of water applied as measured by 'V' notch.
'e' 2/3 of the total quantity of rainfall received during the growing period.

The average duty worked for various crops is as follows :

Crops	Average duty for five years (including rainfall)	
Mungari-jonna	163	Dry crops (mean duty 175)
Hingari cotton	265	
Ragi	126	
Wheat	234	
Korra	103	
Groundnut	156	
Paddy	60	Wet crops (mean duty 75)
Sugarcane	90	

Period of water supply

Thirumali Ayyangar [1942], in his report has estimated the supply of water available for irrigation, including evaporation losses as follows :

Months	Cusecs	Metric cubic feet
1. June—October	1,800	18,663
2. October—February	1,800	18,663
3. February—June	600	6,221
Total	4,200	43,547

Since nearly the same figures have been accepted by Raghavan [1946], in his report there is no difference of opinion between the two as regards the available supply of water. On the assumption that water received from rains would supplement the requirements of the crops either for earlier cultural operations or for further growth of the crop both the officers mentioned above have suggested supply of water for four months only in both the seasons. The area estimated to be brought under irrigation is therefore, considerable.

Since the tract is subjected to frequent failure of rains, the idea of depending on rains is not a sound one in a scheme designed for the successful and assured production of crops. An assured supply of water up to the final stages of crop growth is essential. As already stated restricting water supply to four months is beset with serious difficulties and many of them could be easily overcome if water is given for eight months. The points that are against restricting the supply to four months and

those that are in favour of eight months supply will have to be considered carefully before a final decision regarding the distribution of water is fixed.

The points for consideration are as follows :

Four months irrigation. (1) For the *mungari* season (June to September), it has been recommended that water need not be supplied after September and the crops if necessary can get on with the 'fair' amount of rainfall, normally received in August, September and October. Under the project conditions water is let into irrigation channels in June and it takes more than a fortnight to reach the tail end. Experience has shown that the cultivators will start preparatory cultivation only after the receipt of water and not earlier. As such the sowing will naturally extend from about the middle of June to about the middle of July and the harvest of most of the crops will be over only by about the end of October. Hence, irrigation water will have to be given till the end of October and not till the end of September, as programmed.

In this connection, it is worthwhile to mention the experience gained in the Bhagavadi Farm, which is about five miles from Siruguppa where water is given free to watch the reactions of the cultivators, when the project matures. From the records maintained by the special staff or the Agricultural Department stationed in this village the information regarding the cropping calendar adopted is mentioned below :

Crop	1944-45		1945-46		1946-47	
	Sowing	Harvest	Sowing	Harvest	Sowing	Harvest
(a) *Jonna*	2 July	22 October	28 June	21 October	9 June	30 September
	1 August	13 November	9 July	28 October	12 June	22 October
(b) *Korra*	6 July	22 October	28 July	29 October	..	
	30 July	10 November	..	..	..	..
(c) Chillies	..	..	15 July	29 September	24 June	19 September
	..	..	6 August	13 February	19 July	28 February
(d) Ground nut bunch type	..	..	22 July	25 October	16 June	28 September
	..	..	27 July	7 November	24 June	21 October
(e) Maize	..	..	..	..	13 June	10 September
	..	..	..	..	24 June	17 September

It is observed that the sowing of *mungari* crops generally extends up to the end of July, while the harvesting is up to the end of October. This clearly indicates that water in the *mungari* season is required up to the end of October.

Regarding the *hingari* season where water is programmed to be supplied from October to end of January trials conducted have shown that cotton, when sown late suffers adversely in yield but when sown in August and September gives remunerative yield. Water should therefore be made available in the *hingari* season from August.

If water is given only in October the choice of crops will be restricted. Only wheat, Bengal-gram, maize, vegetables and onions could be grown successfully. Instead of supplying water to the cultivators for four months in *mungari* and four months in *hingari* season, continuous supply of eight months from June to January will be advantageous as detailed below:

(1) The cultivators will be assured of a continuous supply of water, without the fear of supply being cut off at the fag end of the crop, involving serious disaster.

(2) The cultivators will have a wide choice of crops to grow and diversified farming could be adopted.

(3) There will be sufficient scope to grow green manure crops and plough it in the soil. This will be the most practical and cheapest way of building up the soil fertility of the vast tract proposed to be irrigated in the absence of sufficient supply of cattle manure. The addition of organic matter will improve the 'tilth' and drainage of the black soil.

(4) With eight months supply of water the combinations of crops that could be raised are indicated below:

Crops	From	To	Duration
1. Ladies finger and tomatoes	June	August-September	3½ months
	September	January	5 ,,
2. *Korra* and Cambodia cotton	June	August-September	3½ ,,
	September	February	6 ,,
3. *Ragi* and onion	June	October	4½ ,,
	October	February	4½ ,,
4. Maize and cotton	June	August-September	3½ ,,
	September	February	6 ,,
5. Groundnut bunch and maize and	June	August-September	3½ ,,
	September	November-December	3½ ,,
Green manure and or fodder	December	February	3½ ,,

Crops	From	To	Duration
6. Chillies	June	January	7 months
7. Groundnut (bunch) and Cambodia cotton	June	August-September	3½ „
	September	February	6 „
8. Groundnut (bunch) and gloomed wheat	June	September	3½ „
	October	February	6 „

The tract has very thin population (167 per sq. mile) and the economic condition of the *ryot* is very poor; besides, labour and livestock are inadequate. Under these conditions it is highly problematical whether the proposed 2·5 lakhs of acres could be brought under cultivation with the restricted supply of irrigation in both seasons. On the other hand, if the area is reduced and continuous supply of water is assured for eight months there are greater chances of the entire area being brought under intensive cultivation immediately.

If a continuous supply of water for eight months is assured for the wet lands, there is a good opportunity for increasing the production of pulses. A long duration paddy giving higher yield than the short duration ones, could be grown from June to November followed by a pulse crop from November to February.

Summary

The Government of Madras in co-operation with the Government of H. E. H. the Nizam of Hyderabad, has taken up the construction of a dam across the Tungabhadra to launch an irrigation project to protect part of the area in Bellary and Kurnool Districts, in the Madras Presidency, and part of the area in Hyderabad State, frequently affected by famine.

Experiments conducted at the Agricultural Research Station, Siruguppa have indicated that the injurious salts present in the black soils get washed down with irrigation and there is no upward rise of salts due to evaporation of soil moisture.

Crops that could profitably be raised in both seasons viz., *mungari* (June to October) and *hingari* (October to January) have been fixed.

There is clear evidence to indicate that it is desirable to supply water for irrigation purpose from June to January instead of restricting them to four months in either season.

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INFLUENCE OF SOME OF THE ENVIRONMENTAL FACTORS ON THE YIELD OF GREEN FODDER AND SEED IN BERSEEM IN THE PUNJAB

By H. R. Saini, M.Sc., B.Sc. (Edin.)., Deputy Director of Agriculture and
H. C. Malik, B.Sc. (Agri.), Associate, I.A.R.T., Fodder Botanist, Sirsa

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Berseem (*Trifolium alexanderinum*), an excellent fodder crop, though not indigenous to this country, has come to occupy a position of great eminence in the farm economy of the irrigated areas of the province. According to the latest figures available, collected through the courtesy of the Deputy Directors of Agriculture in the Punjab, 266,075 acres were put under it in 1944-45. These figures, however, do not represent the actual state of affairs, as most of the records of the area of winter fodder crops like *senji* (*Mellilotus parviflora*) and *shaftal* (*Trifolium resupinatum*) are mixed in it. Area under the crop would expand enormously, but the supply of adequate quantities of good seed is a great limiting factor in its wide spread cultivation. The demand to some extent is met by importing it from the N.-W. F. P. but in this case its cost is so high that it is beyond the means of the average farmer to purchase it. Berseem is capable of giving very high yields of green fodder in four to five cuttings from November to May under suitable environments, and the fodder is highly nutritious and palatable. This fact is evident from the percentage of various constituents, revealed through chemical analysis given below.

Chemical analysis of berseem of five cuttings of green fodder

Cut	Ash	Fat	CF	Protein	N.F.E.	HCl soluble ash	CaO	P_2O_5	K_2O_5	Mn_3O_4
1st cut	19·03	1·29	24·49	17·44	37·75	16·31	3·75	0·46	5·91	·0174
2nd cut	15·27	1·45	27·62	12·87	22·79	14·23	3·55	0·29	4·54	·000
3rd cut	20·12	1·47	8·87	12·0	47·56	15·26	4·06	0·52	4·86	·00086
4th cut	16·43	1·79	27·27	11·94	42·57	15·92	3·22	0·45	5·17	·00036
5th cut	14·52	2·40	26·73	11·20	45·15	12·0	2·63	0·69	3·74	·0058

Berseem is a highly restorative crop, not only for improving the fertility of the soil on which it is grown, but has also shown great superiority over other crops in reclaiming alkaline soils.

With the growing knowledge and popularity of berseem as an ideal winter fodder crop, great difficulty began to be experienced for the supply of adequate quantities of its good seed to the cultivators of the Punjab. The seed, as mentioned above, was mostly imported from the N.W.F.P., which in addition to being extremely costly, contained a lot of chicory (*Chicorium intybus*) seed. Even the Department

had no other course than to arrange for berseem seed from that province. The cultivators also rightly or wrongly, began to believe that N.-W. F. P. seed was superior to that raised in this province, because of the favourable climatic conditions obtaining there ; but this alone could not be taken as a very strong reason for ruling out the possibility of raising good berseem seed in this province.

As in other crops, it is generally to be anticipated that the behaviour of imported seed is likely to be somewhat different in a new habitat, because of the great variation in the temperature, rainfall and soils of different localities. The aim of the present investigation was, therefore, to study the extent of variation in yield when berseem was raised from seed imported from the N.-W. F. P., in comparison with the crop raised from seed produced in the Punjab.

Berseem is a modern fodder crop which has the prospects of extensive expansion but adequate and up-to-date knowledge regarding its various agronomic aspects, based on the results of definite experiments, is very limited. With a view to obtain reliable data, as a part of the study of the experiments designed to determine the influence of source of seed on yield, effect of the following factors was included in the present investigation :

1. Influence of date of sowing on yield.
2. Influence of the interval between two successive cuttings on yield.
3. The suitability of some other crops for growing mixed with berseem for augmenting its yield of fodder from the first cutting.
4. Influence of the time, at which the crop is left to mature seed, on its yield of seed.

Influence of source of seed on yield of berseem

Climate is the most important single factor, which restricts the limits within which a crop can be successfully grown. Though there are wide differences in the soil and climatic conditions, such as temperature, rainfall and altitude of the Punjab, and the N.-W. F. P., berseem seed had to be imported at a very high cost from that province, because good quality seed was not available in the Punjab. The heavy cost of its seed was, however, a great limiting factor in its large scale expansion in the irrigated areas of the Punjab. The problem of producing berseem seed in this province, therefore, was very urgent. With this end in view, extensive experiments were conducted at the Fodder Station, Sirsa from 1939 to 1945 to see if good quality berseem seed could be raised in the Punjab, and to compare the performance of seeds raised in the N.-W. F. P. and in the Punjab, both for outturn of fodder and yield of seed.

Review of literature

A number of investigations have been reported in the literature, on the extent of variation in the yield of different crops, as a result of the influence of source from which the seed was obtained, but none has been reported in the case of berseem. Schafer *et al* [1921] reported slight variations in the yield from a comparison of Washington and Manitoba wheats at Washington, the former being superior, yielding

41·12 bushels, and the latter yielding 40·62 bushels per acre. Sprague [1935] reported that varieties of corn, introduced from other States, were almost invariably inferior to the well adapted local strains. Bayles [1936] found significant variation in yield in only three out of 91 individual seed lots, produced under different environmental conditions, from other seed lots of the same variety.

As a result of the studies of various experiments in Europe, Piper [1937] reported that locally grown seeds gave better yields than those brought from a distance. In the United States this phenomenon was well-known in the case of highly bred crops like corn, but was not recognized to any great extent in the case of grasses and clovers. He ascribed the higher yields of crops raised from local seeds to their adaptation and acclimatization, and elimination of inferior individuals. In plots of orchard grass, grown side by side in Virgina, the New Zealand strain was distinctly shorter and apparently inferior by about 20 per cent. Under Swiss conditions Stebler found French seed to be the most satisfactory, and the American seed only slightly inferior, though it was late. Seeds from Switzerland, Holland and Germany gave in each case practically as good results as those from France, while the New Zealand strain proved inferior to others.

Tests conducted for a period of three years to determine the amount of hay produced from seed from different sources, namely, the United States, Denmark, Germany, France, Sweden, Australia, New Zealand, at three experimental stations in Denmark, showed that American strain was superior to the European at the two stations; while Australian and New Zealand gave smaller yields by about 20 per cent.

As regards the influence of source of seed on alfalfa, it was concluded by Piper that the best results were as a rule secured from locally grown seeds, provided there was no difference in variety. Investigations conducted in Germany and France, regarding the relative behaviour of plots sown respectively with seed of American and European alfalfa from different sources, indicated that yield of hay from American seed was the best, and that it was also more subject to mildew than the European.

Similar experiments in America showed that in general Southern grown seeds were not favoured in more Northern regions, because they were inferior to cold resistance.

Ulrich *et al* [1944] reported insignificant variations in sugar-beet production by growing it under different climatic conditions at two locations, with the same seed and fertilizer, and attributed the differences in production to climatic conditions.

It is apparent from the various references mentioned above, that source of seed has very little influence on yield, and it is more due to the climatic conditions that variation in yield is observed.

MATERIAL AND METHODS

The experiments herein reported were planned to determine the effect of source of seed on yield of green fodder and seed, and were conducted at the Fodder Research

Station, Sirsa, in the South East Punjab from 1938-39 to 1944-45, *viz.*, for a period of seven years. Similar experiments were conducted at some other Agricultural Stations also.

The average annual precipitation at Sirsa is approximately 10 in. of which about 1·5 in. occurs during the crop growing season from September to April-May. Drought frequently occurs, however, and is perhaps the chief limiting factor to otherwise successful crop production in that locality—as a matter of fact in the whole of the Punjab.

Berseem seed was imported from two different places, Peshawar and Bannu with almost similar conditions of climate in the N.-W. F. P. and from a number of places in the Punjab, viz., Montgomery, Multan, Gurudaspur, Sargodha and Lyallpur, representing varied conditions in the irrigated areas of the province.

The experiments to study the influence of source on the yield of green fodder and ripe seed, were conducted according to the randomized system of field trials in blocks varying from six to eight in number and each block consisting of three to eight ecotypes of berseem. The size of unit sub-plots varied from 1/40th to 1/80th acre. During 1939-40, however, one experiment at Sirsa was arranged according to the Latin Square System with six ecotypes and six repeats in unit sub-plot of 1/100th acre. The seed used in these experiments was of the Mescavi variety only, which has been found to do comparatively much better than other varieties usually available in Egypt. The rate of seeding normally varied from eight to twelve seers per acre, and sowings were carried out at the normal sowing time, that is, in the end of September or early October by broadcasting inoculated seed in standing water.

The yields of green fodder and seed, obtained from these tests, were analyzed statistically and the results were considered significant when 'F' value exceeded the expected values at one per cent and five per cent levels of significance.

To start with in 1938-39 comparisons of the N.-W. F. P. and Punjab berseem seed, both as regards yield of green fodder and seed, were under way at Sirsa and Lyallpur, where the crop raised from Punjab seed gave higher outturn of fodder and seed ; but later on experiments were extended and conducted at various Departmental Agricultural Stations, except Rawalpindi, in order to obtain definite data regarding the behaviour of these seeds under varied conditions.

Discussion

It is well-known that good quality berseem seed is bright yellow, while poor quality seed contains brown and immature seeds also. The seed obtained from different sources was, therefore, analyzed into its components on the basis of colour of seed, viz., yellow, yellow-brown, brown and immature, etc., both as regards weight of these components and the number of seeds in each. The requisite analysis of seeds on the basis of ten grams weight of each sample for the two years 1939-41, is given in Table I.

TABLE I

Analysis of seed obtained from different sources on the basis of 10 gm. weight

	Source of seed		1939-40				Total	Per cent germination	1940-41					
			Yellow	Yellow brown	Brown	Immature			Yellow	Yellow brown	Brown	Immature	Others	Total
1.	Sirsa	Weight	5·56	3·07	0·30	1·07	10·0	79	6·850	2·305	0·250	..	0·595	10·0
		Number	1865	1183	127	578	3753		2634	1145	288	..	..	4067
2.	Montogomery	Weight	5·20	3·72	0·68	0·40	10·0	89	4·220	3·835	0·985	0·200	0·760	10·0
		Number	1591	1239	230	89	3149		1432	1387	431	288	41	3579
3.	Multan	Weight	4·57	3·10	0·83	1·50	10· 0	81	5·200	3·620	0·9100	0·215	0·229	10·0
		Number	1688	1165	325	643	3821		1837	1370	361	105	17	3690
4.	Jhang	Weight	5·75	2·68	0·52	1·05	10· 0	77	..	..	..	..	..	..
		Number	2100	946	190	657	3893		..	..	..	..	..	..
5.	Sargodha	Weight	8·48	2·47	0·40	0·65	10· 0	84	4·430	3·670	1·900	0·255	0·555	10·0
		Number	2376	822	144	265	3607		1363	1271	376	243	*nil*	3253
6.	Gurdaspur	Weight	6·46	1·97	0·20	1·37	10·0	81	5,950	3·000	0·330	0·400	0·320	10·0
		Number	2508	734	82	828	4125		1933	1132	144	208	*nil*	3417
7.	Risalewala	Weight	..	..	..	..	..	89	5·000	3·735	0·880	0·200	0·185	10·0
		Number	..	..	..	..	..		1533	1283	329	108	*nil*	3283
8.	Hansi	Weight	..	..	..	..	..	75	2·180	3·815	2·485	0·025	0·720	10·0
		Number	..	..	..	..	..		783	1603	1541	9	*nil*	4225

TABLE I—*contd.*

Analysis of seed obtained from different sources on the basis of 10 gm. weight

	Source and seed		1939-40				Total	Per cent germination	1940-41					
			Yellow	Yellow-brown	Brown	Immature			Yellow	Yellow-brown	Brown	Immatrue	Others	Total
9.	Jullundur	Weight	..	..	..	..	..	..	4·150	1·550	nil	1·965	2·335	10·0
		Number	..	..	..	..	..		1584	648	nil	1050	733	4015
10.	Delhi	Weight	..	..	..	..	..	81	5·800	3·400	0·180	0·320	0·300	10·0
		Number	..	..	..	..	..		1983	1562	211	173	85	3969
11.	Peshawar	Weight	6·29	2·40	0·36	0·95	10·0	88	6·650	1·620	0·42	0·160	1·240	10·0
		Number	2223	879	131	309	3542		2393	650	198	100	838	3679
12.	Bannu	Weight	6·07	1·81	1·27	0·85	10·0	89	..	..	..	..	..	..
		Number	2171	682	489	316	3678		..	..	..	..	..	..

The analysis given in Table I shows clearly that there is great variation in the different components, viz., yellow, yellow-brown, brown and immature seeds in the various samples. During 1939-40, Gurdaspur and Sargodha samples had the highest weights (6·46, 6·48 gm.) and numbers (2508 and 2376) of yellow seeds; Peshawar and Bannu samples were close seconds as their weight and numbers were 6·29 and 6·07 and 2223 and 2171 respectively. It is indicated that seed superior in quality to the N.W.F.P. seed could be raised in some parts of the Punjab. In the year 1940-41, Sirsa seed had the highest weight, 6·86 gm. and 2634 yellow seeds per 10 gm. of the seed samples and Peshawar sample was a close second with 6·65 gm. weight and 2393 grains, while there was very little difference in samples obtained from other parts of the province. Hansi sample had the least weight (2·180 gm.) and number (783) per ten gm. The climate and availability of irrigation water at the flowering and seed setting time have a determining influence on the development and maturity of seed, and good quality seed can be raised in some parts of the Punjab in good years. These seeds were sown for conducting the comparative fodder and seed yield tests. The results obtained are given in Table II.

TABLE II

Mean yield of green fodder from berseem raised from seed obtained from different sources
Acre yield in maunds and seers

Sources of seed

Year	Experimental Station	N.-W.F.P.		Punjab						Significance at	
		Peshawar	Bannu	Sirsa	Montogomery	Multan	Lyallpur	Gurdaspur	Sargodha	1 per cent	5 per cent
1938-39	Sirsa	904-20	958-20	810-0	1002-0	*nil*	*nil*	*nil*	*nil*	14·12	10·31
1939-40	Sirsa 1	888-0	996-0	958-0	988-0	1002-0	*nil*	1070-0	1048-0	7·79	5·83
	Sirsa 2	695-0	762-0	842-20	*nil*	*nil*	812-20	*nil*	*nil*	11·50	8·43
	Sargodha	371-0	*nil*	*nil*	360-0	*nil*	*nil*	*nil*	336-0	Not significant	
	Montgomery	681-0	*nil*	822-0	708-0	..	..	..	..	15·14	10·23
1940-41	Sirsa	510-0	548-0	520-0	516-0	*nil*	544-0	648-0	530-0	18·74	13·97
	Montgomery	589-0	..	616-0	652-0	*nil*	648-0	..	..	Not significant	
	Hansi	473-16	..	527-16	..	..	..	..	..	13·9	9·17
	Lyallpur	226-0	..	..	..	..	248-0	..	..	Not significant	
	Multan	702-2	..	758-8	..	763-21	..	..	..	Not significant	
1941-42	Sirsa	803-0	..	822-0	729-0	..	..	790-0	667-0	14·28	10·05
	Montgomery	320-0	..	371-0	366-0	..	311-0	..	.	Not significant	
	Gurdaspur	317-24	..	323-8	..	..	..	..	..	Not significant	
1942-43	Sirsa	986-0	910-0	1089-24	1080-0	..	..	1022 0	1028-24	Not significant	
1943-44	Sirsa	1090-16	..	1281-24	1339-20	..	1155-8	1332-0	1235-8	82·61	0·50
1944-45	Sirsa	937-0	..	1032-0	1043-0	..	1066-0	1064-0	1027-0	Not significant	

TABLE III

Mean yield of seed in maunds and seers per acre from berseem seed obtained from various sources at different Experimental Stations

Year	Experimental Station	N.-W.F.P.		Punjab							Critical differences at	
		Peshawar	Bannu	Sirsa	Montgomery	Multan	Jhang	Lyallpur	Gurdaspur	Sargodha	1 per cent	5 per cent
1938-39	Sirsa	1-2	1-39	5-0	9-27	*nil*	*nil*	*nil*	*nil*	*nil*	1-13	0-38
1939-40	Sirsa	0-½	0-1/2	2-18	1-0	0-24	1-15	*nil*	0-25	0-18	0-4½	0-3½
1939-40	Sirsa	0-2	*nil*	*nil*	*nil*	*nil.*	*nil*	1·9	..	..	0-4·2	0-3-6
1940-41	Lyallpur	0-35	*nil*	*nil*	*nil*	*nil*	*nil*	10-28	..	..	..	..
	Sirsa	0-6	*nil*	2-22	2-17	*nil*	*nil*	2-26	2-9	2-11	0-34	0-25
1941-42	Sirsa	5-29	*nil*	12-9	11-5	*nil*	*nil*	*nil*	11-25	10-10	12-4	9-1
1942-43	Sirsa	0-28	*nil*	6-33	6-14	*nil*	*nil*	*nil*	7-7	7-12	20·3 Significant	14·9
1943-44	Sirsa	2-28	*nil*	7-8	8-24	*nil*	*nil*	7-36	7-36	8-0	2·11 Significant	1·52
1944-45	Sirsa	5-18	*nil*	11-12	13-6	*nil*	*nil*	13-5	10-34	8-3	2·67	2·03
	Total	16-7/9	2-0	48-16	52-13	0-24	1-15	35-24	40-16	37-9	..	..
	Average	1-32	2-0	6-2	7-19	0-24	1-15	7-5	6-29	6-8	..	..

Reviewing the results of experiments given in Table II, it is apparent that out of sixteen experiments, results of eight were significant and in favour of the locally produced seed. In the remaining eight experiments, though differences in yield of green fodder of crops raised from the two different sources were not significant, yet they were invariably higher in the case of local seed. The highest yields of green fodder were recorded at Sirsa in 1943-44, when the crop from Peshawar seed yielded 1090 maunds per acre, and that from the Punjab seed gave an outturn of 1339 maunds per acre.

Results of seed yield trials given in Table III also show conclusively the superiority of local seed over the N.-W.F.P. seed. In all nine tests have been reported and in all cases results were highly significant and in favour of local seed. In the year 1944-45, when seed setting was very good in berseem crop the highest yield 13 maunds 6 seers of seed was obtained from the local seed crop as compared to five maunds 18 seers from the Peshawar seed crop. The plants from Peshawar seed are rather spreading in nature and have comparatively more tillering capacity. On this account and on account of their long growing period in the N.-W. F. P. the Peshawar and Bannu seeds are capable of giving one light cutting of green fodder in addition as compared with the Punjab crop, but this can happen only under favourable conditions of irrigation and season. The total yield of green fodder, however, is practically the same in both cases. To substantiate the statement made above a partial summary of results obtained during the year 1940-41 is given below :

	Place of comparison	Yield per acre of green fodder from		Differences in favour of Punjabi or Peshawari seed	Yield of seed per acre from			
		Punjab seed	Peshawar seed		Punjab seed		Peshawar seed	
		Maunds	Maunds	Maunds	Maunds	Seers	Maunds	Seers
1.	Jullundur	913	800	+113	..		..	
2.	Multan	764	702	+ 62	..		..	
3.	Montgomery	652	589	+ 63	..		..	
4.	Sirsa*	584	470	+114	2	22	0	6
5.	Hansi	527	473	+ 54	..		..	
6.	Lyallpur†	248	226	+ 22	10	28	0	34
7.	Gurudaspur	207	173	+ 34	.		..	

* Sirsa crop was allowed to mature seed after 3 cuttings of green fodder.
† Crop was allowed to mature seed after two cuttings.

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The yields vary very much both from year to year and from one Experimental Station to another. During 1939-40, the yields were poor at the Fodder Research Station, Sirsa, but were very encouraging during 1940-41 and 1944-45, from which it can be concluded that it is more due to the favourable climatic conditions that good setting in berseem can be obtained, than to anything else. If some showers of rain are received during the winter season in February, March and April, which tend to keep the season mild, and the temperature somewhat below 100°F., the setting is very good, and as a result high yields of seed are obtained; but in the absence of winter rains, when hot and dry winds begin to blow early in the season, and irrigation water is also available in limitted quantities, setting is adversely affected, resulting in very low yields of seed.

The source of seed had a very remarkable influence on the yield of seed of the two crops, viz., those raised from the N.-W.F.P. and the Punjab seeds. The former as is mentioned above, is more tillering and late flowering than the Punjab crop. The result is that the periods of development of flowers and seed synchronize with the hot season, which invariably starts from the end of April, and thus adversely affects both, and consequently results in low yields of seed. It may, therefore, be inferred that the crop from the Punjab seed is superior, and gives higher yields of seed than the crop raised from the N.-W. F. P. seed.

Taking the results of the seven years collectively, it is apparent that the N.-W. F.P. seed yielded about 1 maund 32 seers to 2 maunds seed, while the Punjab seed gave as high as seven maunds of seed per acre, which is a very good average yield of berseem seed.

In view of this, it has been definitely proved that berseem seed can be raised successfully in some tracts of the Punjab, and that this seed is superior to the N.-W.F.P. both as regards green fodder and seed production.

2. *Influence of date of sowing on yield*

The optimum time of sowing of crops has come to be established as a result of long experience, and in the case of berseem, which is a newly introduced crop, it has been found to extend from the end of September to early October in the Punjab. But there is no definite experimental data to indicate the best sowing time and the extent of variation in yield, when sowings are made at different times during this period, or they are delayed on account of some factors beyond the control of the farmer. Work to some extent has been carried out at some of the departmental Experimental Stations, but systematic studies to find out how differences in yield express themselves in relation to varying times of sowing, have been very limited. The various environmental factors have a definite influence on the physiological activity of the plant, which in turn influences yield.

Extensive studies have been reported regarding the influence of date of sowing on yield of crops, but very few have been reported in the case of berseem. Some preliminary experiments carried out at the Indian Agricultural Research Institute, New Delhi in 1940-41, showed that the best yield was obtained from a crop sown on October 15. The other dates in order of merit were October 1, November 1,

December 1 and 15 and November 15. Usually authors agree that yield decreases as the sowings are delayed. Engledow and Ramiah [1930] noticed remarkable effect of late sowing on yield in wheat, and attributed the differences to the influence of season. Adair [1940] and Hadeyet Ullah [1944] found consistent reduction in yield with delayed sowings. That yield of wheat was adversely affected by late sowings was reported by Singh and Alam [1944] also. From some of these instances it will be apparent that time of sowing is a very important factor determining yield in crops. The present investigation was, therefore, conducted to find out definitely the most suitable time for sowing berseem in order to get maximum, yield.

Mescavi variety of berseem, which has been found to do well in our climate, was sown at varying intervals from the middle of September to the middle of November, during the last four years from 1942-1946 at the Fodder Research Station-Sirsa. The experiment was conducted in randomized blocks with unit subplots of 1/45th acre, keeping three dates of sowing, in six repeats. The size of the unit plot varied in other years. It was 1/55th in 1943-44 and 1944-45 and 1/72th in 1945-46 and sowing dates were increased to four in 1943-44 and five in 1944-45 and 1945-46. Similar dates could not be kept in the successive years 1944-45 and 1945-46 because of the late running of the canal. The crop was sown with inoculated seed in standing water with the usual seed rate of ten seers per acre. It was, however, not possible to stick to the same dates of sowing every year, because sowings were controlled to a great extent by the availability of canal water. The cuttings of green fodder were taken as and when the crop was ready. Table IV shows the total yield of fodder obtained from varying sowing dates in the year 1942 to 1946.

TABLE IV

Mean yield of green fodder per acre in maunds when berseem is sown at varying intervals

Year	Dates of sowings					Significance per cent C.D.
	10/9	17, 18/9	24,25/9	1/10	11/10	
1942-43	..	1235	1165	1172	..	Not significant 1 per cent 5 per cent 117·65 77·32
1943-44	1088	1339	1203	1301	..	Significant 15·45 10·9
1944-45	883	1243	1507	1287	1155	Significant 67·57 48·19
	11/10	20/10	24/10	5/11	13/11	.. ..
1945-46	442	448	405	401	317	Significant 40·75 29·93

Yield of green fodder per acre is of prime importance in berseem and any increase in it is a direct gain to the cultivator. It is rather the most complex physiological character, being the result of a number of interacting environmental factors. Total yield of green fodder per acre, in berseem, obtained from a number of cuttings, as shown in Table IV, indicated, that sowings made at weekly intervals during the second fortnight of September up-to the 1st week of October, viz., 17/9, 24/9 and 1/10, have given the highest outturns, as compared with sowings, either carried out earlier, or later than these dates. Each sowing represents a particular set of environmental conditions, which are likely to have a great influence on the germination and stand, and consequently vegetative growth of the crop. The season, due to very high temperature in the very early sowing, is adverse for good germination and uniform stand of the crop. Moreover, the crop in the very early sowings is also dominated to a very great extent by the rank growth of weeds, and this hinders normal development of berseem seedlings. In sowings made later than the beginning of October, the growth period is decreased, thereby causing reduction in the number of cuttings of green fodder, and thus reduction in its total yield. The different conditions influence the physiological conditions of the plant, their relative influence varying with the time of sowing.

It will also be observed from the table that yields of green fodder were exceptionally high in 1942-43 and fairly low in 1945-46. Though high yields in 1942-43 were due to initial soil fertility of the Fodder Research Station, Sirsa, the season had a tremendous influence on the growth of the crop. Winter of 1945-46 passed absolutely dry which resulted in the early advent of hot and dry winds, which influenced very adversely the yield of green fodder and seed.

Since seed setting depends upon the time at which the crop is last cut for green fodder, this aspect has been dealt with separately.

3. *Influence of the intervals between two successive cuttings on yield of green fodder*

Berseem is capable of giving a number of cuttings of green fodder during its growing period. The period taken by the crop to become ready for cuttings, varies with the season, fertility of the soil and the availability of irrigation water. Instances have been noticed, where seven to eight cuttings of green fodder have been obtained under a system of good farm management, yielding invariably more than 1000 maunds per acre. Naturally in such cases the crop becomes ready for cutting in about thirty days or so. But cases are not infrequent when berseem crop has made such poor growth as to give hardly two or three cuttings of green fodder, yielding 300 to 400 maunds per acre only. Though the number of cuttings and yield will be controlled by the factors mentioned above, it is necessary to know, as to what is the desirable stage of growth, when the crop cut will not only give the highest outturn in that cutting, but will also allow its subsequent quick growth. With this end in view, an experiment was conducted in randomized blocks in six repeats at the Fodder Research Station, Sirsa in 1944-45 and extended to other farms in 1945-46 by keeping twenty, thirty, forty, fifty and sixty days intervals between two successive cuttings. Sowings were carried out with common Mescavi variety, as usual with inoculated

seed, broadcasting it in standing water. The mean yields per acre obtained during two years under varying intervals are given in Table V.

TABLE V

Mean yield of green fodder per acre under varying intervals between the two successive cuttings

Mean yield per acre in maunds

Year and station	Cutting intervals in days					Significance at	
	20	30	40	50	60	1 per cent	5 per cent
1944-45							
Sirsa	410	683	925	1006	1003	40	50
1945-46							
Sirsa	318	620	668	574	448	58	115
Gurdaspur	512	944	960	992	704	338	245
Multan	506	784	813	838	673	73	53
Hansi	439	609	618	508	501	64	47

Earlier in 1941-44 similar tests were conducted at Lyallpur Agricultural Station with the following results :

Mean yield per acre in maunds cutting intervals (days)

Year	15	30	45	60
1941-42	212	298	719	660
1942-43	350	366	523	589
1943-44	346	659	1016	965

Berseem makes luxuriant vegetative growth under favourabe conditions of soil and moisture, and takes about a month or so to become ready for successive cuttings after the first cutting. This period, however, varies under different conditions. From the yield of green fodder obtained under varying intervals between two successive cuttings, it can be definitely concluded that 40 days interval is the best, yielding on an average 800 maunds per acre. These results confirm the earlier trials conducted at Lyallpur, where 45 days interval was found superior to others. Khan and Singh [1946] concluded that very low yields of green stuff were obtained in either 15 or 30 days cutting intervals, because high frequency of cutting affected adversely the sprouting capacity of the crop, and as a result a considerable number of plants dried up early in the season. They also did not favour the cutting

interval of 60 days, because by that time fodder became very fibrous and developed some unpleasant odour, as a result of which fodder was not relished by cattle. It can, therefore, be recommended that cutting interval in berseem, should in no case exceed 50 days, while highest return can be expected, when cuttings are taken at intervals of 40 days.

4. *Influence of the time at which crop is left to mature seed on its seed yield*

There are conflicting opinions as to the most suitable time at which the berseem crop should be left to mature seed. It is claimed in certain quarters that the crop, when left after taking second cutting in February, sets very good seed, some consider middle of March to be the optimum time from the economic point. Sayer [1935] reported that good seed was formed at all farms in the Punjab. The number of cuttings to be taken before the crop was left to form seed varies with the fertility of the soil, last cutting being taken preferably by the first week of March or by the middle of March at the latest. Still others think that beginning of April also is not even late for good seed setting. As a matter of fact this period is also primarily controlled by the vagaries of season and availability of irrigation. In the N.-W. F. P., where the growing season is long and remains very favourable for seed setting up to the end of June, the crop is left in the end of April, and yet sets very bright yellow seed; but in the Punjab the season becomes fairly hot, and the crop left at that time gives very low yields of poorly developed and immature seed. In order to establish the most suitable time for this purpose, experiments were conducted at the Fodder Research Station, Sirsa, and other farms in the year 1943-46. The sowings of these experiments were conducted as usual in replicated randomized blocks in unit sub-plots of 1/55th acre and six repeats with inoculated seed of Mescavi berseem at the optimum sowing time. The yields of seed, obtained under a system of varying dates of cutting, after which crop was allowed to mature seed, are given in Table VI.

TABLE VI

Mean yield of berseem seed per acre, keeping varying dates of last cutting (in maunds and seers)

Year	Station	Dates of last cutting				Significance at	
		15/2	1/3	16/3	31/3	1 per cent	5 per cent
1943-44	Sirsa	9-23	8-27	3-32	3-18	0-36·7	0-26
1944-45	Sirsa	11-13	12-5	12-25	8- 7	1-2.	0-30
1945-46	Sirsa	0-22	0-29	1-17	1-27	0-39	0-28
	Gurdaspur	2-8	3-20	2-32	2- 7	0-19	0-14
	Hansi	2-32	1-38	1-10	0- 1	..	2-14
	Multan	2-15	1-37	1-30	1- 8	Not significant	
	Montgomery	3-9	2-23	2-10	2-28	Not significant	
	Total	20-30	19-14	13-10	11- 9	..	..

The yield of seed of any crop is the ultimate result of all the physiological activities of the plant, which are controlled by a number of factors. Among them temperature, humidity, fertility of the soil and availability of irrigation at the seed setting time, are the most important. The length of growing period, which is also determined by the temperature, is another limiting factor in successful seed setting. It is apparent from the yield of seed obtained after taking the last cutting at varying times during 1944-45, at the Fodder Research Station, Sirsa (Table VI) that earlier the crop was left to mature seed, higher was the yield of bright yellow and plump seed. Yield, however, decreased as the date of last cutting for green fodder was delayed. This was probably the most favourable season for seed setting, because very high yields were secured even after the last cutting on 31 March. But yields of seed were very low during 1945-46 at all the departmental farms, where this experiment was conducted. The seed setting season in this year remained absolutely dry, and the low humidity resulted in early advent of hot season, which in turn influenced both setting and development of seed. The setting was very low and the seed remained shrivelled. It can, therefore, be concluded that the crop left after the beginning of March gave satisfactory yields ; but in case irrigation water is not available at the flowering and seed setting periods, crop left earlier may also give lower yields than the crop left late in the end of March.

The low yield of seed in berseem is not due to the season alone, which varies to a very great extent from the middle of February to the end of March, because it gradually becomes hot and dry, but also depends upon the number of visiting insects, which is also highly reduced in the month of April and May, when crop left late in the season is in full bloom. Bees and particularly honey bees, which are the primary agents concerned in the pollination of berseem flowers, multiply and remain active during the mild season of February and March, and their activity is considerably reduced in the month of April and May. Even in the mild season berseem would not set seed if these insects are not allowed to visit the flowers. Earlier work conducted in this connection showed fairly conclusively that berseem would not set seed more than 0 to 2·5 per cent, if inflorescences are bagged and insects are not allowed to visit the flowers. The effect of hot and dry season, therefore, firstly to retard the growth by reducing the number of tillers per plant and the number of infloroscences, and secondly to reduce the number of bees, and thus decreasing the extent of fertilization of flowers. The lower number of inflorescences coupled with lower pollination and withering of a large number of flowers, results in very low yields of seed from the crop, left to mature seed late in the season. From the economic point of view, however, the additional cutting of green fodder taken compensates for the low yield of seed in this case.

5. *Suitability of some of the non-legumes for growing mixed with berseem for augmenting its yield in the first cutting*

Berseem plant, to start with has a single stalk and a very few tillers, and it is after the first cutting that it tillers perfusely ; consequently the total amount of green stuff is much lower in the first cutting than in the subsequent cuttings. Moreover, green fodder is very scarce from the end of October to early December, because

kharif fodder crops are over, and *rabi* fodder crops are not ready for harvesting. It is only the early sown berseem which becomes ready for first cutting in about the middle of November, but its yield is low because of low tillering in the early stages. In earlier stages, therefore, it would allow other crops to grow along with it. To find out which crop can be raised along with it to augment its yield during the first cutting without affecting the subsequent growth, experiments were conducted in randomized blocks with five repeats in unit sub-plots of 1/80th acre each, by comparing the crop grown alone, with berseem sown mixed with other *rabi* crops such as *rapes* (*Barssica compestris* Var. *Napus*), *oats* (*Avena sativa*) and *Senji* (*Mellilotus parviflora*) for a period of four years from 1942-1946. The sowings were carried out at the proper sowing time by broadcasting the mixed seed in standing water, keeping in view the proportion of different seeds mixed with berseem. Growth was fairly satisfactory in all cases, but rapes grew more quickly than others due to their inherently quick growing character, while oats and senji having long growing periods, grew slowly and were not able to make as much growth as rapes, and consequently added comparatively little green stuff to the first cutting of berseem. But to obtain definite data, experiments were conducted, and the yields obtained are given in Table VII.

TABLE VII

Mean yield of green fodder per acre in maunds from berseem sown alone and in mixture with other crops

Year	Station	Berseem alone	Berseem and rape	Berseem and oats	Berseem and senji	Significance C.D.	
						1 per cent	5 per cent
1942-43	Sirsa	1112	1400	1286	1200	Significant 25-25	18-12
1943-44	Sirsa	1334	1665	1445	1325	Significant 183-34	134-25
1944-45	Sirsa	1145	1224	1141	1130	Not significant 117-8	85-8
1945-46	Sirsa	614	718	597	..	Significant 78-31	57-27

The yields obtained definitely point out to the superiority of rapes in augmenting the tonnage of green stuff of berseem in its first cutting, which is due to the leafy quick growth of this crop as compared with other crops. It is, therefore, definitely concluded that rape is the best crop that can be sown mixed with berseem for increasing its yield in the first cutting.

Summary

Berseem (*Trifolium alexanderinum*), Var. *Mescavi*, which has adapted itself to the climatic conditions of this country, was grown for a study of the influence of some of the environmental factors on the yield of green fodder and seed. The experiments were laid out in the randomized block design at the Fodder Research Station, Sirsa and some of the departmental Experimental Stations.

Yield of green fodder is not influenced to any appreciable extent by the source of seed. Crops raised both from the Punjab and the N.-W. F. P. seeds gave almost equal yields under favourable environmental conditions. The differences were significant in a few experiments only, and in most cases yields obtained showed that they were not due so much to the influence of the source of seed as to the effect of climatic conditions and availability of irrigation in the locality.

The source of seed had a very remarkable influence on the yield of seed of the two crops. The plant from the N.-W.F. P. seed is more tillering and later flowering than that from the Punjab seed. As the seed setting period of the former synchronises with the hot season during April and May, the development of seed is adversely affected, resulting in poor setting and shrivelled seeds. The data of seven years indicated that the Punjab seed is much superior to the N.-W. F. P. in seed this respect, the former yielding on the average seven maunds, while the latter giving an outturn of 1·75 maunds to two maunds of seed per acre.

In view of these conclusions, it has been established that good berseem seed can be raised in the Punjab under irrigation, and that this seed is as good as that from the N.-W. F. P. for raising a crop of green fodder, while it is much superior so far as seed production is concerned.

The period from the third week of September to early October is the best for sowing berseem in order to secure the maximum tonnage of green fodder. Sowings made earlier than this become highly infested with weeds, and sowings later than this give low yields of fodder due to decrease in the number of cuttings.

Maximum yield of green fodder is obtained if 40 days interval is kept between two successive cuttings. This is closely followed by 50 days interval.

The crop gives good outturn of bright yellow and plump seed, if it is allowed to mature seed after taking the last cutting by the end of February or the beginning of March. Cuttings taken after this reduce the growing period of the crop and seed setting season synchronises with the hot and dry season, which result in the reduction of the number of inflorescences and number of honey bees, and thus influence both seed setting and seed development.

Rape has been found to be the most suitable non-legume for sowing mixed with berseem in order to augment its yield in the first cutting.

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PRELIMINARY OBSERVATIONS ON THE BIONOMICS OF POTATO TUBER MOTH (*GNORIMOSCHEMA OPERCULELLA* ZELL.) AND ITS CONTROL IN BIHAR, INDIA

By B. S. LALL*, Bihar Agricultural College, Sabour Bihar, India

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THE problem of storage of potatoes has been drawing the attention of various workers in India since 1907. Lefroy [1910] described durations of different stages of the potato tuber moth (*Gnorimoschema operculella* zell.) and its fecundity and recorded that the eye-buds are the points of infestation and recommended storage of potatoes in thin layers under sand mixed with naphthalene or charcoal. Woodhouse and his colleagues [1911-13] confirmed these findings and found that dipping of potatoes for five minutes in crude oil emulsion before storage, increased rots in storage. Mann, Nagparkar and Kasargode [1920] recommended cold storage and fumigation of the tubers with carbon-bisulphide. Vyas [1930] recommended storage of potatoes under cinder or charcoal. Helson [1942-44], in Australia, found dusting of the tubers with magnesite (20 lb. per ton of potatoes) in the store and spraying with phenothiazine (one lb. per galllon of water) for protecting the potato crop from the infestation of the moth in the field, satisfactory. Lloyd [1943-46] in New South Wales, found two per cent DDT dusting suitable for reducing the moths' infestation on plants in the field and on seed-tubers in the stores. Cannon [1947] in Queensland, recommended dusting of the potato seed tubers with two per cent DDT prior to storage. The foregoing review indicates that sufficient information is not available on the biology of potato moth particularly under field condition in India. Dusting of potato tubers with DDT is not advisable, the insecticide being toxic to human beings, specially in Bihar where seed and table potatoes are not stored separately. Therefore, stress has been given in this paper on such insecticides which are not toxic to human beings. The applicability of DDT has been confined to spraying of the walls or roofs of the godown in order to effect a check on the population of the moth during the period of storage.

In order to carry out detailed investigation, I. C. A. R. sanctioned a research scheme on the pests and diseases of stored potatoes in Bihar. Work under the scheme was commenced in 1943. The following brief notes record important conclusions arising out of the investigation on the moth.

NATURE AND EXTENT OF DAMAGE

The moth causes injury to potatoes in the field as well as in the godown. The damage to the leaf is minor and is heaviest from November to February. In the case of a young plant, it does not exceed 2·13 per cent. The infection of the underground tubers starts towards the middle of February and is maximum in the month of March. At the time of harvest in February, 0·3 to 3·33 per cent of the tubers was found infected with the caterpillars. Under the sand method of storage as

* At present, Department of Entomology, Cornell University, Ithaca, N. Y., U. S. A.

practised in 'Bihar-sharif' and 'Patna city', about 20 per cent of the potatoes get destroyed by the moth, as against cent per cent of potatoes if they are kept exposed in the godowns. The caterpillars infecting the tubers increase the rot and the rot in turn provides ideal conditions for the rapid multiplication of the pest. All the caterpillars which hatch out from the eggs laid on the eye-buds of the tubers, do not penetrate the tubers through the same eye-buds but scatter themselves on the surface of the tubers for finding suitable spots for penetration. Ordinarily an eye-bud is penetrated by a single caterpillar. Some times, the number of caterpillars within a tuber exceeds the number of its eye-buds. It is probably due to the scarcity of healthy tubers in the neighbourhood of the infected ones. A maximum of 16 caterpillars was noted within one tuber.

Sources of infection

Field. The possibility of the infestation reaching the field through the infested seed tubers was thoroughly investigated, and it appears that the chances of the moth emerging from under soil where the seed tubers are buried, are little. About 23·9 per cent of the caterpillars on hatching from eggs laid on the eyes of the tubers were able to penetrate the seed tubers under soil while 12·3 per cent of the caterpillars came out from infested seed and formed earthen cocoons in the proximity of the tubers. The seeds carrying eggs germinated quite well but those initially infested with caterpillars rotted due to bacterial brown rots (*Phytomonas solanacerum*). The only possible source of infection in the field is the moths which quit the stores in the month of September and settle on brinjal and tobacco seedling before migrating to potato crop in the month of November.

Stores. Infestation in the stores arises from the infested tubers brought from the field as well as by the moths flying from the field into the godowns.

Bionomics

Life-history

From November to January when the plants are green, the pest breeds exclusively on the foliage. During the months of February and March, when the plants dry up, the moths hide themselves amongst dry leaves on the ground or in cracks of the soil. The moths seldom fly during the day and if disturbed their flight is short and snappy. On alighting they again seek shelter. They are active in the field soon after sunset and fly about for an hour. The moths are observed flying after sunrise also in the months of February and March, but the flight is of very short duration. During the morning flight, the male moths are predominant, the proportion being three males to one female. In the stores the moths have been observed to feed on rotten potatoes. The juice of rotten potatoes increases longevity, fecundity and the ovipositional period of the moths. Honey solution can also sustain the moth (Table I). The eggs are laid on rough scars or under the torn skin of potatoes as well as on the eye-buds of the tubers. In sprouted potatoes, the eggs are laid on the base of the sprout.

TABLE I

The effect of different foods on the fecundity and the ovipositional period of the moth

Treatments	Number of trials	Average oviposition period in days	Average fecundity per female
Honey and water (1 : 10)	20	6·8	89·5
Glucose and water (1 : 10)	20	6·4	69·5
Gur and wate (1 : 10	20	6·4	59·4
Juice of rotten potatoes	20	7·1	102·0
Juice of healthy potatoes	20	5·6	57·8
Control	20	5·2	19·7

The nectar of the flower of *Lantana camera* which grows widely in the neighbourhood of the potato fields of Bihar-sharif and Patna city. appears to be one of its natural food plants. The moths frequently visit the flowers of *Lantana camera* at dusk during February and March. The nectar of *Lantana* flower increases longevity as compared to those of 'perol' (*Luffa acutangula*) and cucumber (*Cucumis sativa*) which are also largely cultivated in these localities near the potato fields (Table II).

TABLE II

Showing the effect of different nectars on the longevity and fecundity of the moth

Nectars from	Number of moths	Average longevity	Average fecundity
Lantana camera	25	6 days	82·3
Solanum nigrum	25	5 days	39·5
Cucumis sativa	25	5 days	44·7
Luffa acutangula	25	4 days	42·8
Without food	25	3 days	32·6

The eggs are more or less oval in outline and creamy white in colour. When freshly laid, the eggs are covered by a water-soluble secretion which hardens on exposure and cements the eggs to the eye-buds of the tubers or to the surface of the leaf. As the embryonic development proceeds, the dark colour of the larval head capsule and prothoracic plate become visible. When ecolosion takes place, the chorion remains behind as a colourless shell. The average incubation period is three to four days during summer and five to six days during winter.

For one or two hours before emergence, the larvae may be seen moving within the chorion of the eggs. The larva eats its way out of the chorion through an irregular opening. The newly hatched larva measures about 1 mm. in length. The mature larva attains a length of 11 mm. and is creamy-white in colour with a light brown head. The larva undergoes four moults before pupating. On foliage the young larva begins to mine the leaf soon after emergence and lives in the mine during November to January when the plants are green. It cannot penetrate the entire length of the shoot so as to reach the tuber under soil. The maximum length of the shoot bored by a larva is about an inch only. During February to March, when the eggs are laid on soil, the young larva penetrates through the cracks of the soil and bores into the tubers. In the stores, the caterpillars, when full grown come out of the tubers, crawl upwards through the layer of sand covering below two inches thick, and on reaching the surface, make sandy cocoons. If the eggs are laid on the sand under which potatoes are kept, the larva on hatching penetrates the sand in search of potatoes. The first instar caterpillars are incapable of penetrating through the sand layer even half an inch thick. Dispersal of the pest from one tuber to another also takes place in the caterpillar stage. The larval period lasts seven to five days in summer and sixteen days in winter.

The pupa is light green in colour when first formed but soon becomes dark brown. Pupae vary in size, but the average length is about 7 mm. The pupa male is slightly smaller than the female pupa. If potatoes are kept under the cover of sand, the larva makes a sandy cocoon but when the infested potatoes are kept without any cover, silken white coooons are formed on the eyes of the tubers, between two touching tubers, in cracks of the walls and in the empty sandy cocoons lying about, in the godowns. When the pest is breeding on the tubers under soil, the full grown caterpillars utilize earth or dead leaves to construct the cocoons. When the caterpillars are feeding on the foliage, white brownish cocoons are formed. Pupation takes place in dry curled leaves on plants, or dry fallen leaves and in cracks on the ground. The pupal period lasts five to four days in summer and nine days in winter.

Mating usually takes place during the evening hours both in the field and in the stores. One male is capable of fertilizing as many as ten females during its life time. The mating of a female moth with the same male over and again does not affect the potency of their reproduction (Table III). The longevity of the male moth increases to nine days when it mates with different females as against five days when it is kept together with the same female during its life time. The trials were carried out for eight times under the same conditions.

TABLE III

Showing the number of moths fertilized by a male and total number of eggs laid by such fertilized moths

Serial number	Average number of eggs laid by female moths fertilized by one male									
Male	1	2	3	4	5	6	7	8	9	10
1	31	49	63	96	22	60	3	88	55	*nil*
2	39	126	36	2	59	10	*nil*	*nil*	*nil*	*nil*
3	15	71	86	66	86	21	51	75	99	32
4	39	27	47	23	11	57	61	55	27	*nil*
5	33	74	45	7	24	89	31	52	11	*nil*
6	10	25	56	13	70	17	39	40	36	*nil*
7	22	30	16	21	23	14	21	33	*nil*	*nil*
8	47	51	23	31	29	10	12	27	11	*nil*

An analysis of the population of the moths in different potato stores has revealed that the females are numerous more than males, the ratio being 3:2. Therefore under natural conditions also, a male may mate more than one female. Inside stores, the time for mating is between 7 p.m. and 6 p.m. while, in the fields it lasts from 4 to 5 p.m.

Oviposition occurs throughout the day and the night, but is at its maximum from 6 p.m. to 7 p.m., in summer and from 4 p.m. to 5 p.m. in winter. The moth lays eggs in depression, mostly on the under surface of the leaves during the months of November and January while during the months of February and March it lays eggs directly on the tubers if they are accidentally exposed. The fecundity of the moth is very low during the winter months (November to January). The rates of fecundity and the longevity of the moth is greater in February and March when temperature is higher (Table IV). In the stores the moths, in the absence of exposed potatoes, oviposition any object, such as walls, sand-coverings and their own sandy cocoons.

TABLE IV

Showing the fecundity and longevity of the moths in different months

Month	Average minimum temp. F.	Average maximum temp. F.	Average relative humidity per cent	Average fecundity female moths	Average longevity of female in days	Average longevity of male in days
July	83·0	87·0	77·3	85·5	5	4
August	82·5	89·4	81·8	81·0	5	4
September	84·1	88·7	76·0	68·5	5	4
October	80·1	85·9	69·0	78·0	5	4
November	68·6	78·8	60·7	58·6	4	3
December	61·8	69·0	55·0	49·5	4	3
January	68·0	80·0	64·0	67·7	4	3
February	68·0	80·0	64·0	79·7	5	4
March	72·0	86·0	73·0	82·5	5	4
April	79·2	88·6	63·6	89·8	5	4
May	86·0	102·0	51·2	105·4	5	4
June	86·8	98·2	66·2	98·1	5	4

The rate of development of the pest is accelerated with the rise of the temperature up to 38°C. The temperature 40°C. proved fatal for all the stages. The temperature 20°C. is the lower limit for its development. In laboratory trials, the fecundity of the moth decreased to 12·6 eggs in darkness as against 28·86 eggs in light. It is probably for this reason that the darker godowns in Bihar-sharif and Patna city had lower infestation. The moths are only active during dusk.

Thirteen broods were observed during the year, eight of which were in the stores and the remaining five in the field. In stores the duration of the different stages was : incubation period three to four days, larval period seven to five days and pupal period five to one day. In the field : the incubation period five to six, larval period sixteen days and pupal period nine days.

STORAGE METHODS PRACTISED IN DIFFERENT LOCALITIES

The various methods of storage practised in different localities of Bihar have been studied. The important conclusions are :

(i) Godowns with a minimum of light but having good ventilation show lower incidence of the moth. Such a condition is obtained by fixing two or

three ventilators 1ft. ×1ft. in size near the ceiling so that cross ventilation occurs.

(ii) Godowns with mud wall and *kacha* floors are the best for storage during April to June, because they keep cool. The sand, the most common covering material is quite successful in checking the incidence of the pest if applied two inches thick but this increases the rot. With a view to reduce the rot, the store-keeper resorts to various devices with the advent of rainy seasons; the thickness of the sand is reduced or the tubers are transferred to the '*machan*' and kept uncovered. In some places the potato heaps are sprayed with water during April and May on alternate days to lower the temperature.

(iii) In some cases potatoes are washed in water before they are stored. This removes nearly 30 per cent of the eggs of the moth.

The potato store-keepers are fighting against the tuber moth and rotting. The conditions which reduce the incidence of the moth, unfortunately, increase the rots and the conditions which inhibit the rots favour the moth. The potato store-keeper, therefore, tries to meet the greater of the two evils. When the season is favourable for the moth attack, the storage conditions are such as to control the moth, and when the season is not favourable for the moth, but very favourable for the rots, the store-keeper takes the risk of the moth attack and tackles the rots.

Preventive and control measures

In the store

Pretreatment. Pretreatment with various dips, e.g., anifilum, turpentine oil, pyridine, phenyl and creosote were tried as disinfectants. A dip in five per cent phenyl solution for fiftteen minutes is most effective. It disinfects the tubers completely of viable eggs. Turpentine (five per cent) solution showed higher larvicidal effect but increased the susceptibility of the tuber to rots. Five per cent solution of creosote also brings about complete disinfection of the tubers from the eggs but it is liable to induce the high percentage of rots in subsequent storage of potatoes.

Covering materials. A comparative study of different covering materials had shown that one inch thick covering of sand containing pieces of garlic or crushed onion (one lb. per md. of potatoes) is better than two inches thick layer of sand lime (one inch thick) or charcoal one inch thick. Storage of potatoes on *machan* during April to June proved detrimental on account of dessication and rot, but it was helpful in reducing fungal rots during July to September. Storage on brick floor during April to June was very efficacious against heat-rot but it was not so helpful from the point of view of fungal rot during July to September. The total recovery of potatoes under sand and garlic covering was 60·83 per cent on *machan* as against 48·73 per cent on brick-floor under the same covering during the period from April to September. The recovery of potatoes increases to 65·53 per cent if potatoes are stored on the brick-floor from April to June and on *machan* during July to September under the same covering. Garlic repels the moth.

Trap. To study the possibility of petroleum oils as an attractant for the moth, the experiments were carried out at Sabour, Bihar, with kerosene oil, pine oil, turpentine oil, the proportion being one part oil and 200 parts water. The tests were carried out in an infested potato godown at Sabour by keeping the mixture over night in earthen pails and counting the catches every morning as reported in the Table V. The largest number of moths were attracted to the kerosene oil trap but the difference between these oils was not very large.

TABLE V

Baits	Days of catches 1 ♀	♂	2 ♀	♂	3 ♀	♂	4 ♀	♂	5 ♀	♂	6 ♀	♂	7 ♀	♂	Total moths trapped
Pine oil water 1 : 200	73	64	61	47	69	71	16	24	20	11	18	9	6	3	490
Turpentine oil : water 1 : 200	75	85	58	21	57	47	18	12	59	85	5	4	9	5	537
Kerosene oil : water 1 : 200	83	31	34	68	45	49	76	20	88	28	14	8	8	4	552
Control (water)	4	3	1	2	7	1	3	2	4	1	1	*nil*	*nil*	*nil*	29

A suitable trap has been evolved for destroying the moths during storage in the light of above observations. It consists of 18 in. diameter earthen basin containing water with a film of kerosene oil on its surface. It may be used both during day and night in potato-stores. At the end of every week the water of the basin should be changed. The trap was repeatedly tried in the infested potato-stores at Sabour, Bihar-sharif and Patna city. In these demonstrations the catches averaged 159·3 moths per trap per day. One trap was found quite sufficient for a store-room, measuring 24ft. × 18ft. × 10ft. The kerosene oil acts as an attractant for the moths. This trap is gaining great popularity amongst the cultivators of Bihar-sharif and Patna city on account of its efficacy and cheapness.

Recent developments in the widespread use of DDT as spray on the interior surface of the buildings or store-room to control insects like house flies and mosquitoes, have necessitated exploring the possibility of the insecticide to be used in white-wash on the interior surface of the store-rooms in Bihar, to destroy the moths during the storage period. For performing preliminary trials, earthen pots fitted with lids were white-washed with chalk containing different strengths of DDT. Including the control, there were four treatments, each treatment, having three replications. In each pot along with healthy potatoes, six pairs of moths were introduced to study their fecundity and longevity. To study the residual effect of the white

wash, repeated tests were made in the same pot and it was found that the toxic effect of the wash persists for about a month. The longevity and the fecundity of the moth are very considerably reduced with three per cent DDT white-wash (Table VI). Further work on this item is in progress.

TABLE VI

Showing the longevity and fecundity of the moth under different DDT treatment

Treatment	No of trials made	Average longevity	Average fecundity
DDT (1·5 per cent)	8	4·7	42·9
DDT (2 per cent)	8	3·6	49·3
DDT (2·5 per cent)	8	1·3	21·0
DDT (3 per cent)	8	1·1	19·5
Without DDT	8	5·8	111·2

Spraying the walls of potato stores with 10 per cent solutions of phenyl and creosote after an interval of every week has proved very effective in keeping down the population of the moths in the stores. The phenyl and creosote treatments have repellent effect on the moth.

It is essential to sort out rotten potatoes and remove them from the stores at regular intervals to prevent infestation to healthy potatoes.

In the field

Harvesting of the tubers before the middle of February is recommended as it has three distinct advantages. Firstly, the infection in the harvested tubers is almost nil. Secondly, potatoes are less liable to infection by the moth during harvest as their population is very low at that time. Thirdly the temperature of the soil will be below 85°F. and there will be no risk of heat rot during subsequent storage. The potato crop becomes quite ripe for harvesting by the middle of February in Bihar. The crop usually remains for a period of three and a half months in the field.

When the irrigations are increased from six to eight during the growing period of the crop from November to February, the percentage of infection in the underground tubers at the time of harvest falls from 3·4 per cent to 0·5. The potatoes should be kept or transported in baskets treated with 10 per cent solutions of creosote or phenyl at the time of digging out potatoes from under the soil.

The control of the pest in the field by dusting or spraying does not seem practicable due to: the caterpillars either mine the leaves or under ground tubers, the eggs are usually found in depression on the under surface of the leaves and therefore not easily accessible to insecticidal sprays. The kerosene oil trap may be used at dusk for trapping the moths which are very active at that time.

SUMMARY

The potato tuber moth causes injury (i) to leaves, stems and the tubers of the growing crop in the field and (ii) to stored potatoes in the godowns. The leaf damage does not exceed 2·13 per cent during November to January. In store, about 20 per cent of the tubers get destroyed by the moths under the sand storage method. The carry over of the pest to the field does not take place through the infested seed-tubers. The only possible source of infestation in the field is the moths which fly out of stores in the month of September and settle on brinjal and tobacco seedlings before migrating to the potato crop. In stores, the infection is carried through the tubers which received infection while in the field, as well as through the moths flying from the field to potato godowns.

The moths seldom fly in day light and when disturbed, the flight is short and snappy. They are active in the field soon after sunset and the flight continues for about an hour. The moths are observed flying after sun-rise during the months of February and March. In stores the moths feed on rotten potatoes. The juice of rotten potatoes increases longevity, fecundity and the oviposition period of the moth. *Lantana camera* which grows widely in the neighbourhood of the potato-growing areas of Bihar is suspected to be one of its natural food plants. The mating of the moth usually takes place during the evening hours both in the field and the stores. One male is capable of fertilizing as many as ten females during its life time. The longevity of the moth increases to nine days when it mates with different females every day as against five days when it is kept together with the same female. Oviposition occurs throughout the day and night but it is maximum during 6 p.m. to 7 p.m. in summer and 4 p.m. to 5 p.m. in winter. On plants the young larvae mine the leaf soon after emergence and live as leaf miners during November to January. During the months of February and March the larvæ infect the underground tubers in addition to leaves and stems. When the caterpillars are breeding on the tubers under soil, they utilize earth or dry leaves to produce earthy cocoons. In case the pest is breeding on the aerial parts of the plants, brownish-white cocoons are formed. The pupation takes place under dry curled leaves on plants or fallen dry leaves or in cracks of the soil. In the stores if the infected potatoes are kept under cover of sand, the larvae make sandy cocoons but when potatoes are kept without any cover, white silken cocoons are formed on the eye-buds of the tubers.

The rate of development of the pest is accelerated up to 38°C. but a temperature of 40°C. is fatal for all stages of the pest. A temperature of 20°C. is the lower vital limit. Thirteen broods of the pest were noted within a year, eight of which were in the stores and the remaining five in the field.

Thus, it will be advisable to harvest potatoes, which are to be utilized for seed purposes by the middle of February.

Dipping of potatoes in a five per cent solution of phenyl for 15 minutes disinfects the tubers completely from viable eggs. Amongst different covering materials tried, one inch thick sand covering mixed with garlic bits (1 lb. per maund of potatoes) has given the best results both on the floor and on *machan*. The total recoveries

of potatoes under the covering of sand and garlic was 60·83 per cent on *machan* as against 48·73 per cent on brick-floor. The recovery of potatoes increases to 65·53 per cent if potatoes are stored on the brick-floor from April to June and on *machan* from July to September. One kerosene oil trap is quite sufficient for a store room measuring 24 ft. × 18 ft. × 10 ft. Kerosene oil acts as an attractant. Spraying the walls of potato godown with ten per cent solution of phenyl or creosote after an interval of every week has proved very effective in keeping down the population of the moths in the stores.

When potatoes are harvested before the middle of February the infestation in the harvested tubers is almost nil, the potatoes are less liable to infection by the moths during harvest as their population is very low at that time, and the soil temperature remains below 80°F. at that time and therefore there is no risk of *Heat rot* during subsequent storage. When the irrigations are increased from six to eight during the growing period of the crop from November to February, the percentage of infection in the tubers at the time of harvest falls from 3·4 per cent to 0·5 per cent. Potatoes may be transported or kept in baskets treated with ten per cent solutions of phenyl or creosote to avoid the infection by the moth during harvest. The kerosene oil trap should be used particularly during dusk for trapping the moths which are very active at that time.

ACKNOWLEDGEMENT

The writer is much indebted to Dr M. L. Bhatia, M.Sc. Ph.D. (Cantab.) lately Entomologist, Bihar and Dr J. S. Patel, M. Sc. (Cornell.) Ph.D. (Edin.) Principal, Bihar Agricultural College, Sabour for generous help and guidance during the investigation.

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NOTE

THE RAPID DETERMINATION OF MOISTURE IN PROCESSED FRUITS AND OTHER AGRICULTURAL PRODUCTS

By K. SWAMINATHAN, U. SEN GUPTA and S. DAS, Indian Agricultural Research Institute, New Delhi

(Received for publication on 24 September 1948)

EXAMINATION for moisture content of any edible material is one of the essential preliminaries in passing it as a standard product, and its determination assumed greater importance during war times when such materials had to be transported long distances under difficult conditions, because on it depended the soundness of the material at the destination after long periods of transit.

The moisture in ordinary agricultural products is generally determined by drying at 100°C.-105°C. in an air-oven to constant weight. But this method is not applicable to all classes of materials, as for example, processed fruit products. Among the chief difficulties that confront the chemist in determining the moisture content of sugar-bearing materials by the ordinary methods of drying may be mentioned :

> The very hygroscopic nature of such materials, and the consequent retention of water by absorption or occlusion ; the extreme sensitiveness of some sugars, notably fructose, to decomposition at temperatures between 80°C. and 100°C. with the splitting off of water and other volatile products, [Jacobs, 1938], and the liability of many impure sugar-containing materials upon heating to give off various volatile products such as alcohols, aldehydes, esters, organic acids, carbon dioxide and ammonia which are wrongly estimated as water in determining the loss of weight.

The moisture determination is further complicated by the fact that many sugars like maltose, lactose and raffinose retain variable amounts of water of crystallisation under different conditions of drying so that one is not always certain, even when no further loss of weight occurs in the oven, as to the exact moisture that may be retained by a hydrated form. Even sugars containing much glucose generally give too high a result for moisture content if dried at 100°C. owing to the conversion of glucose into glucosan and caramel [Allen, 1933]. It is, therefore, clear that the ordinary methods of moisture determination cannot be suitable for sugar-bearing materials.

In such cases the low pressure drying method of the Association of Official Agricultural Chemists is recommended. But this is time-consuming requiring drying of the material at 70°C. for six hours under a pressure not exceeding 100 mm. Because of this and the uncertainty which sometimes attends the ordinary oven-drying method at 100°C.-105°C. several rapid methods have been proposed for direct

moisture determination. Such methods as distillation with immiscible solvents come under this class.

The then Directorate of Food under the Department of Supply, New Delhi, had been sending during the war years to this Institute samples of raisins, sultanas, briquetted raisins and other dried fruit products for the determination of moisture content to have a check on contractors' products before sending them abroad.

For reasons cited above the Vacuum Drying Method was accepted as the most reliable and accurate method, and accordingly moisture determinations were made by it. Perhaps with a view to be doubly sure of the moisture content before accepting the contractors' samples, the samples were being sent to other laboratories as well. We reported the moisture values to be well within the permissible limit for all samples sent to us. In the case of briquetted raisins the Military Food Laboratory at Kasauli reported a much higher figure and on that account rejected some contractors' samples claiming that the xylene distillation method they followed according to the Standard method of the Ministry of Foods, London, to be correct. They contended that in the Vacuum Oven method the entire moisture was not driven out. The rejection of the contractors' samples gave rise to a controversy between the Food Directorate and the Military Food Laboratory, and the matter was referred back to us to prove by actual demonstration that the Vacuum Oven method was the one to be adopted for dry fruits and the like and the xylene distillation method, in spite of its simplicity and rapidity, yielded abnormally high values as a result of the decomposition of fruits during the boiling of xylene.

In order to prove the destruction of sugars and the consequent increase in the moisture content, samples of fructose, glucose, saccharose, briquetted raisins and nuts were examined both by the low-pressure drying method and the xylene and toluene distillation methods for moisture. Further, reducing sugars were estimated in them before and after digestion with xylene and toluene. It was evident that the percentage of sugars after digestion with the solvents was lower than that in the original samples. Both in simple sugars and fruits there was decomposition and charring during the moisture determination by the xylene distillation method. With toluene the decomposition was less. In the case of fructose which is so abundant in fruits, the decomposition was the greatest. Fructose, in the presence of water, decomposes to oxymethyl furfural with three molecules of water. This extra water is responsible for the higher value of moisture by the xylene method [Browne, 1941].

High boiling point solvents are destructive in their action and give abnormally high values for moisture with charring. Drying in boiling xylene of raisins and briquetted raisins and nuts leads to blackening and considerable decomposition. The blackening is preceded by swelling during which the evolution of moisture is fairly normal, but high in aggregate. Water is evolved as the darkening of fruit intensifies. Fruits first dried by heating in toluene lost more water when subsequently heated with xylene.

Summary

If correct values of moisture for processed fruits and other agricultural products, are desired by the rapid distillation methods, then the solvents employed must be altered according to the nature of the samples.

The toluene distillation method was found to give results comparable with the standard vacuum oven method, when the heating in an oil-bath at about 140°C. is stopped after one hour.

In this connection a short review of time and labour saving methods described in the *Journal of Institute of Brewing* [1936] should be consulted in order to enable one to choose the rapid procedure with due regard to the material on hand for which the moisture content is sought. The three methods of Tate and Warren [1936], Middleton [1931] and Lundin [1932] may be referred to.

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REVIEWS

INSECT PESTS OF COTTON IN INDIA

By H. D. NAGPAL, Indian Central Cotton Committee Publication, 1948, Price Rs. 2

THE book gives a comprehensive list of the insect fauna associated with cotton crop and is the first publication of its kind in India.

The author deserves credit merely for compiling the information which is rather inadequate for scientific workers and is too simple and almost preliminary. The classification of pests is rather vague and does not give any clear idea about the status of the pests. At places the importance of the major pests is shadowed by including them after the minor pests. Mostly the vernacular names pertain to North India and the references are also incomplete.

The publication needs revision and considerable improvement by the addition of further details for making it useful for further critical research on cotton pests. It will be still better if the notes on important pests or on those which are likely to be of some significance are supplemented with sketches or plates to help in the identification of the pests. (K. N. T.)

DISEASES OF COTTON IN INDIA

By B. N. UPPAL, Published by Indian Central Cotton Committee, Bombay 1948, p. 33, Price Rs. 2

THAT a crop which occupies an area of over twenty million acres in India should be attacked by several diseases due to fungi, bacteria, nematodes and viruses, is not surprising. Fortunately, a majority of these diseases in India are of minor importance, only wilt and root-rot in certain provinces and states causing anxiety to the cotton growers. But a disease of no importance today may grow into a menace tomorrow. The Indian Central Cotton Committee has, therefore, done well in bringing together the available information on these diseases and this bulletin, written by a distinguished investigator of cotton diseases, is a welcome addition to the scanty literature on the diseases of crop plants in India.

Under each disease the life-history and distribution are briefly stated, followed by an adequate description and aetiology of the disease. Control measures, wherever they are known, are given and relevant references to important literature further add to the value of the bulletin. The sections on wilt and root-rot are naturally very exhaustive, while those on anthracnose and blackarm, which appear to be not as insignificant as was once supposed, have also been dealt with in detail.

It is to be hoped that in a second edition of this bulletin, there would be a sufficient number of coloured drawings and photographs to illustrate the diseases. Bulletins of this kind should have been distributed free to cotton growers; instead a charge of rupees two, which is rather exhorbitant, has been made, which is very much to be regretted. (B. B. M.)

COMMERCIAL FRUIT AND VEGETABLE PRODUCTS

By W. V. CRUESS, Published by McGraw-Hill Book Company Inc., New York, 3rd Edition, 1948, pp. 906, Price $8.50

THIS internationally distinguished author and his well-read book need no special introduction to the readers. His book has served for over twentyfour years all students of food technology and horticulture and in this third edition the author has put in lots of new material and data as well as many new illustrations. These represent various phases of developments in the science of food technology during the past many years especially in canning, freezing and dehydration. A singular addition to this new edition is the chapter on ' Plant Sanitation ' which deals with a very essential and important aspect of in food processing particularly in the recent years. All the materials have been presented up to date.

The book has covered all the principles and commercial applications of canning, freezing and dehydration of fruits and vegetables, beverage making, manufacture of jams, jellies, marmalades, fruit and vegetable concentrates, pickle making, wine and vinegar making, etc. Some chapters cover the various aspects of spoilage and their control in, utilisation of waste fruits and vegetables and disposal of wastes. An interesting chapter on packing cases and other methods of packing has also been briefly presented. At the end of each chapter a useful reference list of books, bulletins and original articles on the various subjects has been given, which will be of considerable help those who want to go deep into the details.

The subject of fruit technology has shown great progress and possibilities and it is rather difficult to write a single and comprehensive book covering canning, freezing, dehydration, etc., since each one of the branches might well be dealt with in separate volumes. In this edition the credit goes to the author in presenting the whole field in an instructive and informative manner, giving most of the up to date details on the various branches of fruit technology without sacrificing any of the fundamental principles and fresh advances.

The book is recommended to all those engaged in the fruit industy as well as to all the students and teachers of fruit technology. It is the only outstanding ' all-in-one ' compilation so far available dealing with all the processes involved in the manufacture of fruit products and in fruit preservation. The fruit world must be greatly indebted to the author for putting his life-time study and energy in this new edition for its benefit. (G. S. C.)

MGIPC—M—95AR—18-4-50—600.

ORIGINAL ARTICLES

FUMIGATION AND OTHER METHODS OF DISINFESTATION OF PLANT MATERIALS AT INDIA'S PORTS

By Hem Singh Pruthi, M.Sc., Ph.D. and Sc.D. (Cantab.), F.R.A.S.B., F.N.I.,
Plant Protection Adviser to the Government of India, Ministry of Agriculture, New Delhi, India

(Received for publication on 17 March 1949)

(With Plates V and VI)

A NUMBER of very destructive foreign insect pests like the San Jose Scale, Fluted Scale, Woolly Aphis and Potato Tuber Moth and plant diseases such as Bunchy top disease of banana have found their way into India due to lack of proper inspection and disinfestation facilities at our ports and are now causing annually a loss amounting to several crores of rupees to the country and are a menace to the production of food and some other valuable commodities. Fortunately, there are still a very large number of insect pests and diseases in other parts of the world which have not so far entered India*; but with increased commerce and rapid means of communication they may do so any time unless we adopt immediately very efficient plant quarantine measures, as has been done by other agricultural countries, like the U. S. A., Holland, France, etc. The present methods adopted at Indian ports are over 30 years old when scientific agriculture was in its infancy in this country. The need for fully equipped Plant Quarantine Stations at ports—sea, air and on the land frontiers—is of absolute necessity; otherwise our country will very soon be flooded with insect pests and diseases which may ultimately ruin agriculture completely. The Government of India have appreciated the importance of this problem and have decided to establish a quarantine service as a part of the Directorate of Plant Protection, Quarantine and Storage of the Ministry of Agriculture.

Furthermore, we have certain international obligations to meet. Just as we are anxious to see that foreign insect pests and diseases do not enter our country, we should see that Indian insect pests and diseases do not leave this country in plant material and plant products which we export. Not only our reputation is already at stake but Indian commerce is also suffering greatly, because many of the plant products which we export on arrival at the destinations in other countries are found to be infested with various kinds of insects and diseases, often greatly reducing the quantity and deteriorating the quality of the commodity. There is, therefore, also need for disinfestation and certification of all the plant products that we export to meet the requirements of foreign countries as well as in the interest of our own trade. This can only be done with modern technique and a sufficiently large and fully trained plant quarantine staff at our ports.

This article has been prepared for practical use at ports so that the latest procedures are adopted to inspect and disinfest insects by fumigation and other methods, the various plant materials or plant products that are imported into India or are being exported to foreign countries.

A separate Compendium for methods to be adopted against plant diseases will be issued at a later date.

* Appendix III gives some of the more important pests found in various countries, but not recorded so far in India.

Existing facilities and disinfestation methods employed at ports

To prevent the entry of insect pests and plant diseases into India, the Destructive Insect and Pests Act was passed by the Government in 1914. Under this Act and the rules framed thereunder, living plants with the exception of fruits and vegetables meant for consumption, seeds and some other specified commodities, are fumigated with hydrocyanic acid gas at the port (sea) of entry. There is no restriction at present at air ports or land frontiers of India. Importation of foreign plant material is permitted only through seven ports which are Bombay, Calcutta, Cochin, Dhanushkodi, Madras, Negapatam and Tuticorin. The fumigation is at present done by the staff of the Collector of Customs. Thus, the staff carrying out the fumigation have no knowledge of insects which may be infesting the imported plant material nor are they in a position to see the effect of fumigation on them or even on plants under disinfestation. In fact they are not required to do any inspection before or after fumigation. The procedure laid down is in accordance with the directions published in Notification No. 13-C, dated 7 November 1917 of the Government of India, in the late Department of Revenue and Agriculture (*vide* Appendix I). Briefly, there is no inspection, as stated already, before fumigation in order to determine the nature of insect concerned, nor after fumigation to ascertain whether the pests present have been destroyed or not. Moreover, all plants and plant products receive a uniform routine treatment, irrespective of their own tolerance and susceptibility of the pests to hydrocyanic acid gas. In most cases the 'Pot' method of HCN generation is employed, viz. the gas is generated by the action of sulphuric acid on cyanide in a vessel. Wooden boxes (Plate V, fig. 1) with the internal capacity of 98·64 c.ft. or a brick chamber as at Calcutta are used as fumigatoria. For 100 c.ft. of space the chemicals used for the generation of HCN gas are: Potassium cyanide (98 per cent): $\frac{1}{2}$ oz; sulphuric acid and water: 1 fluid ounce each. The time required for the completion of the fumigation process is three quarters of an hour.

At Bombay the fumigation chamber* is 8 ft. $\times$ 6 ft. $\times$ $3\frac{1}{2}$ ft. It is fitted with a fan for circulation of the gas. For the fumigation chamber which has a capacity of 168 c.ft. one ounce each of potassium cyanide (50 per cent solution) and sulphuric acid dissolved in equal volumes of water are used. The packages of imported plant material are unpacked so as to expose the surface of the articles to be fumigated. They are then placed in the fumigation chamber which is then securely closed. The chemicals (KCN and H_2SO_4 solution) are then poured into the respective bottles attached to the generating chamber. In the case of living plants, bulbs, etc. fumigation lasts for three-fourths of an hour, after which the gas is let out by opening a valve at the top and working the fan inside for two hours.

Organization of proper plant quarantine

The above account shows how deplorably primitive are the methods adopted at present. As the insect infestation is not examined either before or after treatment and as the dosage of the fumigant used is uniform without taking into consideration

* This has now been scrapped as unfit for use

the insect concerned and its habit as well as the particular live-plant, the disinfestation as carried out at present may not serve the purpose for which it is intended, the insect never being killed or as it has often happened, the plant succumbing on account of over dosage. There is, at present, no arrangement by which all packing material of plant origin and all the various imported plant products are examined and treated. Experience in other countries, e.g. the U.S.A. during past twenty-five years has shown how foreign insects can enter the country even through these materials. There is also, at present, no arrangement for vacuum fumigation of consignments like cotton and tobacco bales which are too tightly packed to permit penetration of the gas under atmospheric pressure. To organize the latest methods to inspect imported plant material and plant products and adequately disinfest them, the following are desideratum :

1. Plant inspection house fully equipped with fumigants, fumigation chambers, sterilisers, hot water tanks, vats for oil treatment, incinerators, etc
2. Glass houses for growing plants under quarantine.
3. Properly qualified quarantine staff who can examine all imported material and take adequate measures for cleaning such plants and plant products that require to be disinfested.

The Directorate of Plant Protection, Quarantine and Storage of the Government of India (Ministry of Agriculture) is taking steps to provide the above first at the main ports of Bombay, Calcutta and Madras.

FUMIGANTS

Gaseous poisons used for killing insects are called fumigants. The process of using these gaseous poisons is called fumigation. A very large number of fumigants has been tried for plant quarantine work in various parts of the world. Three of the fumigants most commonly used are hydrocyanic acid, methyl bromide and ethylene oxide. Their application as well as of other gaseous poisons is not only safe but also gives best results when plants and plant products are fumigated in tight enclosures.

Hydrocyanic acid

This is one of the most toxic fumigants in use. It is a colourless gas with a boiling point of 25·7°C. (or 78·3 F.). The liquid HCN manufactured by the American Cyanamid Co. is reported to boil at 79·7°F. under normal atmospheric pressure. The freezing point under normal atmospheric pressure is 5°F. The specific gravity of the liquid is 0·6970. Specific gravity of the gas is 0·9348. Molecular weight is 27. On account of its being lighter than air, its diffusion is mainly upwards and outwards. Under normal atmospheric pressure it does not quickly penetrate closely packed materials like bales of cotton or sacks of grain, flour, etc. To overcome this, such materials have to be fumigated in a partial vacuum. *Very great care has to be taken in using this gas.* It should be used only by trained and experienced operators who must also put on gas masks specially meant for use with HCN. The masks used in the U.S.A. are known as type M-27 with renewal canisters of type C-7.

In England, the 'Degea' masks with initial G and a blue filter are used for HCN gas. A mask of the same manufacture with initial J and a blue filter with brown band is specially intended for use with Zyklon. The 'Puretha' mask with initial D and a white filter can also be used for HCN.

For plant quarantine work fumigation is carried out by (i) generating the gas by the Pot method, (ii) using liquid HCN available in steel containers, (iii) using HCN discoids or Celophite units which usually consist of the gas absorbed in fibrous discs of wood or paper pulp and (iv) using Zyklon a proprietary article which consists principally of liquid HCN absorbed in a porous earth known as 'kieselguhr'.

'Pot' method and fumigation. Hydrocyanic acid was first used for economic purposes in 1886 by Coquillet of the U. S. Department of Agriculture for controlling scale insects on citrus trees. This led to the extensive use of what is called the 'Pot method' in the fumigation of orange trees in California. This method is even now used in some ports for fumigating railway freight carriages having cotton seed or foreign raw cotton. Portable equipments for adopting the 'Pot method' for HCN generation are used in such fumigation work. The chemicals used are, sodium cyanide mostly in the form of 'eggs' and sulphuric acid weighing one ounce each. The proportion of these chemicals and water used for fumigating plant material other than living plants is as follows :

Sodium cyanide (NaCN)	1 lb.
Sulphuric acid (H_2SO_4)	1½ pints
Water	3 pints

For fumigating railway freight carriages having a capacity of 4,606 c. ft. 5 lb. of NaCN 'eggs', one gallon of H_2SO_4 and one gallon of water are used against the pink boll worm and the Cotton boll weevil. The portable HCN generator used in this connection consists of a metal cylinder in which a perforated metal basket slides up and down on a central shaft controlled by the pressure developed by the generated gas. All preliminary preparations are made by keeping the end of the HCN discharge tube from the generator properly inside the carriage, the doors completely closed and all openings and leaks sealed with masking tape and thick brown paper. Special warning posters are attached on both sides of the carriage to warn people not to enter or open the doors of the carriage while it is being fumigated. The required quantity of water is first put into the generator through the openings on one side at the top. The necessary quantity of sulphuric acid is then added gradually to the water. This process *should not be reversed* by adding water to the sulphuric acid as it would result in violent reaction. The opening is then carefully closed. The NaCN eggs are then placed in the metal basket which is held above the acid with the help of a set screw until the opening of the central shaft is securely closed and everything is ready for the gas to be generated. The basket having the NaCN eggs is then allowed gently to slide into the acid. HCN gas is evolved immediately and flows out of the discharge hose. In using this apparatus care must be taken to see that the basket holding the NaCN eggs is held out of the acid until the opening in the top of the generator is securely closed. The evolving of the

gas and the resulting pressure is indicated on a gauge. When all the gas has been evolved and passed out, the discharge tube is removed and the opening through which it was placed inside, is also sealed. The gas is allowed to act for eight to twelve hours. The doors of the carriage are then opened.

Liquid HCN in cylinders. The commercial development of pure HCN in the liquid form and the packing of the gas into small containers by absorbing it in an inert material has enabled great strides to be made in fumigation technique. The packing of liquid HCN in cylinders is done by a large number of firms both in England and America. The HCN cylinders are available in several sizes and forms (Plate V, fig. 5). These cylinders should always be kept in upright position and stored in a cool, well ventilated place, shaded from the sun. Particular care to ensure these conditions in India is very necessary. If no arrangement to obtain the above conditions is possible by using artificially cooled rooms, the cylinders may be kept submerged in water.

Operation of liquid HCN cylinders. The construction of HCN cylinders varies to a certain extent with the firms manufacturing them. The mode of their operation also varies with the construction and instructions for this as well as the way in which they are connected with the fumigation equipment, will be given by the manufacturers.

Volatilizer. This is an important part of the fumigation equipment used in connection with HCN cylinders which vaporizes the liquid HCN so that it enters the chamber as a gas (Plate V, figs. 5 and 6). It consists of a copper coiled tube immersed in a tank of water (Plate V, fig. 6). A short length of rubber hose connects the HCN cylinder with one end of the coil while the other end of the coil enters the vacuum chamber through a side connection. The tank of the volatilizer is made of steel with a removable top and is equipped with gauge glass, thermometer and a source of heat which is usually either steam or water heated by an electrical immersion unit. The vacuum in the chamber draws into it the liquid HCN from the cylinder through the volatilizer. The vacuum delivery connection (Plate V, figs. 4 and 5) connects the cylinder with the volatilizer. During operation the copper coil is heated so that as the liquid HCN flows through it, it immediately vaporizes before entering the vacuum chamber.

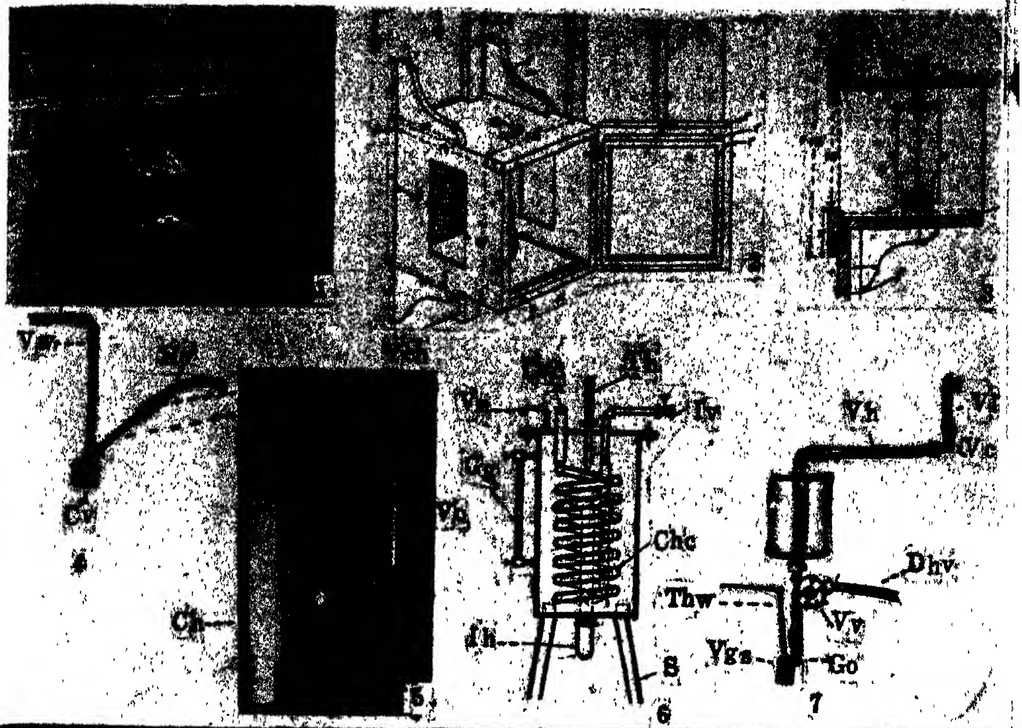
Application of liquid HCN. When very large quantities of materials are fumigated requiring the use of more than a pound of liquid HCN gas, the dosage to be used for fumigation is measured by placing the HCN cylinder on a platform scale. For example, if the dosage of liquid HCN to be discharged into the chamber is 4 lb. and the beam balances at 250 lb. to obtain the required dosage, the beam is moved back to 246 pounds on the scale. Then the valve gas spindle on HCN cylinder valve is opened slowly from half to two turns. Inlet valve on volatilizer is next slowly opened. This permits the liquid HCN to pass into the volatilizer from the cylinder. The introduction of the gas has to be regulated so that the flow is slow enough to prevent the pipe leading from the volatilizer to the vacuum chamber from cooling off appreciably. The scale beam is watched and when it begins to tip indicating that the required dosage has been discharged, the inlet valve on volatilizer

is closed. Then valve gas spindle on cylinder is closed. Inlet valve is opened for a moment to permit the liquid HCN in the hose line to be discharged into the volatilizer. Then, the inlet valve on volatilizer is closed. In the case of small vacuum chambers when the dosage and HCN used is less than a pound, a special 'Measuring Cup' or HCN applicator graduated in ounces having a capacity of ten ounces of liquid HCN is used. Its position and connections may be seen in Plate V, fig. 7. Its tubular lower end is connected to the gas outlet of the cylinder. At the top of the cup is a vent hose which is about 10 ft. with a female connection at each end. The further end of the vent hose has a vent connection which in turn is connected to a vent line. The vent line which consists of soft seamless copper tubing should be run from the operating point outdoors and up in the air for discharge of the gas-laden air which issues from the cup during filling. The discharge hose is 6 ft. in length and has a female connection at the end, which connects it with the valve of the cup and a male connection at the other end which connects it to inlet on volatilizer. A special T-handle is used for operating HCN cylinder valve with measuring cup in its place as shown in Plate V, fig. 7.

HCN discoids or celophite units. These discoids or celophite units consist of HCN absorbed in an inert porous and absorptive material like wood or paper pulp cut out in the form of thin discs. For the purpose of stabilization of the gas the absorbent is acidified. Some manufacturers included a warning gas also. The Aero brand of HCN discoids produced by the American Cyanamid Co., contain HCN of 96 per cent to 98 per cent purity and have a thickness of 0·10 inch. They are packed in 16 oz. cans with discoids of ⅜ in. diameter or in 40 oz. cans with discoids of ⅝ in. in diameter. In England, discoids about 5⅜ in. in diameter and 5/16 in. in thickness each containing one ounce of liquid HCN are available also in cans. The cans containing the discoids have to be opened with special openers. The advantages of the discoids are that (i) the gross weight of the cans is very little, (ii) only a can opener and a gas mask are required for their use, (iii) there is no need of weighing and mixing of chemicals and (iv) as they do not crumble or break they are clean, leave no dirt and can be easily disposed off after the fumigation is completed. The HCN in them is completely vapourized in about one hour after they are distributed.

In India, specially, during hot weather when large quantities of the discoids are to be used at one time, they should be pre-cooled by keeping them in a refrigerator overnight or keeping them immersed in a tub of water and adding ice to keep them cool until needed. The use of dry ice may also be resorted to. In this case about 20 lb. of dry ice would be necessary to be applied to each case containing 24-40 oz. cans, for one to three hours, the longer period being preferable. Individual discoids should never be handled. These discoids are well suited for atmospheric fumigation chambers but in plant quarantine work their best use is in ship fumigation.

Zyklon. This is a proprietary product consisting of (i) a prepared inert porous earth called kieselguhr in which has been absorbed liquid HCN, (ii) a lachrymator and (iii) various stabilisers which stabilise the chemically unstable liquid HCN. Zyklon looks like granulated cork and is packed in tin cans, each can containing a definite quantity of available HCN mentioned outside on the label. The cans are opened



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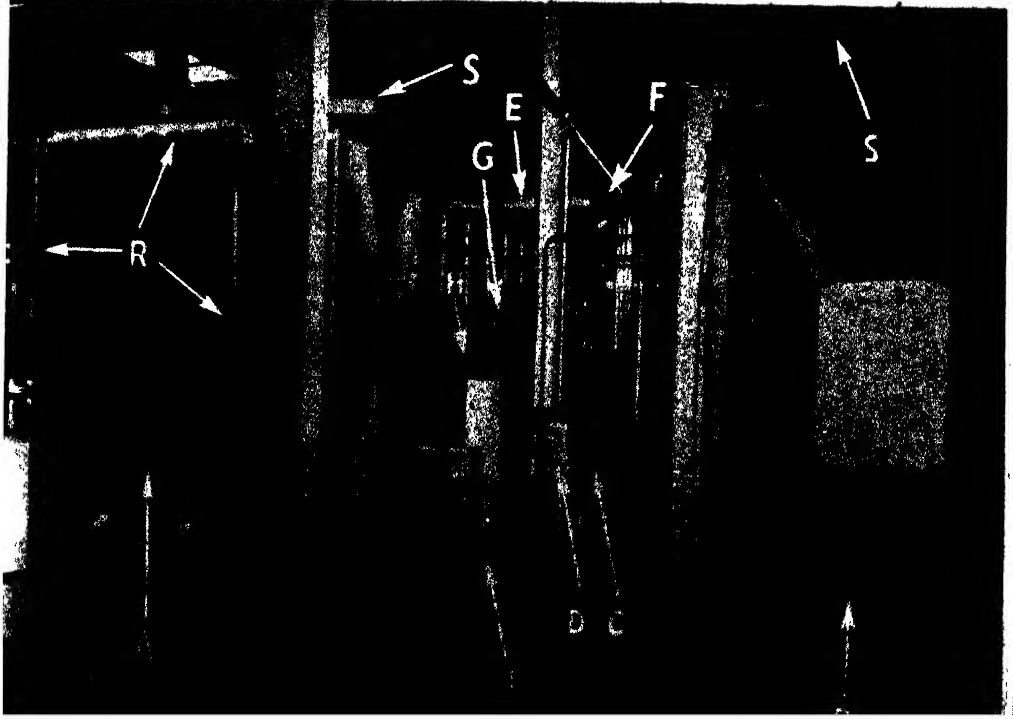

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EXPLANATION OF PLATE V

FIG. 1. Photograph of a wooden fumigation box used at present at some of the Indian port (After Fletcher)

FIGS. 2 and 3. Sketches showing the construction of HCN generating chamber of the wooden fumigation box (After Fletcher)

FIG. 4. Photograph of HCN cylinder valve (*Cv.*) showing the hose to volatilizer (*Hv.*) and the valve wrench (*Vw.*) (Courtesy American Cyanamid Co.)

FIG. 5. Photograph showing the HCN cylinder (*Cy.*) and a volatilizer (*Vo*) placed near the vacuum chamber (*Vch.*) and the connection between the former two. (Courtesy American Cyanamid Co.)

FIG. 6. Diagram to show the construction of a volatilizer. *Cvc* : Connection to vacuum chamber ; *Th* : Thermometer ; *Vn* : Vent ; *Iv* : Inlet valve ; *Gg* : Gauge glass ; *Chc* : Copper heating coil ; *Ih* : Immersion heater ; *S* : Supports. (Courtesy American Cyanamid Co.)

FIG. 7. HCN measuring cup. (Courtesy American Cyanamid Co.) *Vl* : Vent line ; *Vc* : Vent connection ; *Vv* : Valve 'A' ; Vent hose ; *Dhv* : Discharge hose to volatilizer ; *Go* : Gas outlet ; *Vgs* : Valve gas spindle ; *Thv* : T handle wrench (Courtesy American Cyanamid Co.)

FIG. 8. Photograph of a dual vacuum fumigation chamber showing its various parts. (Courtesy Pottstown Metal Product Co.)

A : & B : Rectangular chambers

C : Vacuum pump

D : Volatilizer

E : Suction pipe connecting vacuum pump and chamber

F : Valve in suction line providing control to enable the one pump to evacuate either chamber as desired

G : Vacuum gauge

H : Vacuum breaker valve

J : HCN Cylinder

R : Rubber gasket

S : Roller bearing jib crane on which door is swung

with a special hammer and the contents distributed as desired, usually on sheets of paper so that the residue can be easily collected and thrown off in a dust bin. The addition of a lachrymator or a warning gas in Zyklon provides an additional measure of security for operators both during and after actual operations. It also obviates complicated manipulation of cumbersome apparatus. As Zyklon is packed in light but strong cans, the cost of transportation and handling, as in the case of the discoids is reduced considerably. Another advantage is that it is capable of easy distribution and maximum concentration is obtained owing to speedy exudation of the gas from the large surface area of material exposed.

Fumigation of railway freight carriages with HCN. When a large number of freight carriages have to be disinfected, their fumigation can be carried out in specially large chambers made of concrete. Liquid HCN is used for fumigation, the dosage being 4 lb. per car for eight to twelve hours. In these fumigation houses one to twenty-five carriages can be fumigated at one time. The sliding doors present on each end and between the compartments can be made airtight for atmospheric fumigation. When large quantities of HCN are used, these fumigation houses should have special arrangements with evacuation fans for removal of gas by thorough 'air washing' and tall chimneys so that evacuated gas is released out high up in the air.

HCN fumigation of ships at ports. In modern times shipping lines perform a great deal of fumigation of ships to eradicate cockroaches, bed bugs and rats. Besides these routine fumigations, it has of late been found necessary to fumigate specially cargo ships harbouring dangerous insect pests as a quarantine measure. HCN discoids have been found to be the most suitable for such fumigation work. The following procedure should be adopted when fumigating ships:

1. A day or several hours in advance of the fumigation, notices should be placed in different parts of the ship warning the crew that the ship is to be fumigated at a particular time. If the ship is provided with a loud speaker arrangement, an announcement regarding the fumigation is made over it. In the case of foreign ships this announcement should be in the languages of the crew. All the crew and passengers if any must be asked to leave the ship and they should be taken to a place of safety. The Plant Quarantine Inspector-in-charge of the fumigation should then in company of the ship's Officer-in-charge make an inspection of the entire ship. This is made to find out exactly the places harbouring the pests which need special attention and secondly to determine the presence of any unauthorized persons on board: if any of these are found they should be removed from the ship.
2. The cubic capacity of the ship's compartments, hold, etc. is determined and the amount of HCN discoids to be used calculated.
3. The gangway and all other entrances of the ship are roped off, warning signs are placed at each entrance and a guard posted with strict orders to allow no one on board.

4. All timbers, pipe casings, dunnage, double walls, lockers and drawers and other insect harbouring spaces should be opened up to allow for free penetration of the gas. Bilge boards should be removed when possible, if not all, at least two on each side of the hold. All closets and doors specially those leading to the store rooms in the interior of the ship are opened up. All ventilators and portholes should be covered up and sealed to prevent leakage of the gas. All doors leading from the engine room to the holds and all watertight bulk heads should be closed. At least, two thick tarpaulins should be placed on each hatch battened down as for sea, leaving a small end of the tarpaulin unfastened at one corner of the hatch, for the purpose of scattering the HCN discoid in the hold.

5. The necessary number of containers of the discoids should, then, be placed at the point of their distribution alongside the open corner of each hatch.

6. The Plant Quarantine Inspector in-charge of the fumigation together with the ship's Officer-in-charge should again inspect all spaces to see all persons are out and that everything is ready. A signed statement to the effect that all the ship's personnel have been removed to a place of safety is then obtained from the ship's officer. *This is very necessary.*

7. When the fumigation operator is fully satisfied that everything is in readiness, he should put on a gas mask and proceed to release the discoids from the open corner of the hatch. In the case of fumigation for rats the dosage is ordinarily 2 oz. per 1,000 c. ft. with an exposure of two to three hours. In the case of insects normally it is 8 to 16 oz. per 1,000 c. ft. with an exposure of 12 to 14 hours. In some cases fumigation may have to be repeated so that any insects which survived the first fumigation are killed during the second. The HCN discoid cans should be opened one at a time and the operator standing on the deck must hold the can near the tarpaulin and scatter the contents in the hold. The tarpaulin should then be pulled tight and battened down. Life boats, dunnage on deck, lockers, etc. should also be examined for insects and these also fumigated, if necessary.

8. For fumigating the superstructure, cabins or state rooms at the top, the discoids must be scattered rapidly on to several layers of newspapers previously placed in the rooms to be fumigated, keeping the fibre cap on the container as much as possible between the operations when moving from one room to another. The operation of scattering the discoids from the can should be started at the farthest point from the exit, the operator always working towards the exit. The doors of the state rooms should be quickly closed as soon as the required quantity of discoids are dropped in them. *Gas masks should be worn by the operators during fumigation.*

9. After the ship has been under the gas for the required length of time, the fumigation operators wearing gas masks should remove the tarpaulins

and open up the hatches, ventilators, doors, etc. from the exterior. Ordinarily, the ship is quickly ventilated after fumigation, HCN gas being lighter than air. Difficulty is sometimes encountered in ventilating the holds, in which case a tarpaulin or canvas is hung over the hatch so as to deflect the wind into the hold. If necessary a portable electrically operated blower with a canvas chute can be used in freeing a hold from HCN gas. The superstructure of the ship should not be entered for at least 15 minutes after opening up, and the holds should not be entered for at least an hour.

10. A live rat in a wire cage is lowered to the bottom of each hold and left there for five minutes to test for gas. If the rat is unaffected, the operator-in-charge of the operation may go personally or see one of his men go through all spaces on the ship before it is declared free from the gas. Men making this test should wear gas masks, carry flash lights and be watched from the deck. The presence of HCN after ventilation can also be tested by using methyl orange test papers. These are small strips of orange coloured papers which in the presence of an atmosphere containing HCN, turn pink or red and are very sensitive to relatively low concentrations of the gas. If these test papers do not change within two minutes after exposure to a supposed concentration of HCN, the space is safe for human occupancy.

11. All pillows, mattresses, beddings, clothings, rugs, etc. should be taken on deck and thoroughly aired immediately after fumigation and before being used.

12. All port holes should be opened up for fresh air to enter the cabins.

Precautions to be taken in HCN fumigation. All fumigation houses of Plant Quarantine Stations where HCN fumigation is conducted should be provided with telephone for use in case of emergency. If HCN fumigation is being carried out elsewhere the location of the nearest telephone should be determined for use in case of accident. All operators must carry a bottle containing cubes of ammonium carbonate fortified with strong ammonia to be used as an inhalant in case of accidental inhalation of very small quantities of HCN. It must be remembered, however, that this is not an antidote. Even though very small quantities of HCN or one or two cans of HCN discoids are being used at a time, the operator must wear a gas mask. When opening up a fumigated space also the gas mask must be worn. Gas mask known as M-27 with renewal canisters of the Type C-7 used in the U. S. A. are recommended for use in India. The gas mask can only be used when there is enough oxygen to allow a safety lamp to burn. It should not be used in a concentration of HCN greater than indicated on the canister label. Every time a gas mask is used, after putting it on, it must be tested for tightness. This is done by pinching the hose and inhaling. The mask will collapse if perfectly tight. The life of the canister depends on both concentration of the gas and length of exposure to the gas. If the operator using a gas mask gets a tickling sensation in the throat

or if his eyes start smarting, it is an indication that the canister should be replaced by a fresh one. The operator using the old one should immediately go to fresh air. Canisters are comparatively cheap and should therefore be frequently replaced to avoid any accidents. Very great care must be taken of the gas masks ; they must be kept always in the original case in which they are received from the manufacturers. They must also be kept away from heat, moisture and atmosphere of HCN gas. As light deteriorates the rubber parts of the gas mask, it should not be kept in a glass front case. It is safer to examine a gas mask regularly to see that head harness has not lost its elasticity or that the outlet valve and face piece have no cracks. A stock of fresh canisters must always be ready at hand. All used and discarded ones must be destroyed. *Individuals with punctured ear drums should not undertake HCN fumigation even after using gas masks* although it is reported that such individuals have solved their difficulty by using ear plugs of cotton smeared with oil.

First aid kits used in the U. S. A. in connection with HCN fumigation consists of (i) pearls of amyl nitrite, (ii) ampoules of sodium nitrite, (iii) ampoules of sodium thiosulphate, (iv) one sterile syringe of 10 c.c. and (v) one sterile syringe of 50 c.c. In England, Coramine, Lobeline hydrochloride and caffeine are stocked for such purpose. These must be made available at all fumigatoria in India.

Another important apparatus that all fumigation houses should possess is an inhalator or Resuscitation apparatus. There are several types available administering a mixture of 93 per cent oxygen and 7 per cent carbon dioxide and others administering only oxygen. In England, the two types commonly used are (i) the Novox and (ii) the Novita.

A detailed account regarding artificial respiration and medical aid to be given in case of accidental HCN poisoning is given in Appendix II.

Methyl bromide

Methyl bromide is a comparatively new fumigant. Its insecticidal value was first accidentally discovered in France by Le Gaupil in 1932 when he used it mixed with ethylene oxide to eliminate the fire hazard of the latter. Its use in plant quarantine work in the U. S. A. was due to the efforts of Mackie and Carter. In 1935 it was used to fumigate potatoes against the Potato tuber moth. It is now used for fumigation of different kinds of live plants, fresh fruits, vegetables, potatoes, strawberry plants, citrus fruits, tomatoes, citrus nursery stock, deciduous fruit trees, pears, grains, dried fruits, dried pears, peas, seeds, etc. Fumigation with methyl bromide can be accomplished by means of a partial vacuum in special chambers, at atmospheric pressure, in chambers, in tight rooms, warehouses, railway carriages, under rubberized tarpaulins or in any tight container.

Properties of methyl bromide. Methyl bromide is a colourless, odourless highly volatile liquid, with a specific gravity of 1·732 at 0°C. and with a boiling point of 40·1°F. At ordinary temperatures it is a gas approximately 3·3 times as heavy as air. The properties which make it an ideal fumigant are :

1. High toxicity to a large variety of insects in egg, larval, pupal and adult stages.

2. Low chemical reactivity making it adoptable to a great variety of products including foodstuffs and tender plants because of low absorption, high penetrating power and lack of residual odour or taste.
3. Very low boiling point assuring complete gasification at all temperatures at which fumigation is practicable.
4. Low water solubility permitting the fumigation of products having a high moisture content. This is of great importance in the fumigation of live plants.
5. Low cost per unit of space fumigated because of small dosage required.
6. Ease of application.
7. Non-inflammable and non-explosive.
8. Highly penetrative.
9. Insects once exposed to its vapours under requisite conditions of time, temperature and concentration do not revive bringing about what is called 'delayed mortality'.

Containers of methyl bromide. Methyl bromide is available in 10, 50 and 150 pound cylinders or in one pound cans (Plate VI, figs. 2 and 6). Fig. 1, Plate VI shows the appearance of a cylinder. In order to facilitate rapid and complete removal of the liquid, a valve is fitted on the cylinder with a pipe reaching to the bottom of the container. Natural vapour pressure on the cylinders at 50°F. is 4 lb. per sq. inch; at 60°F.—8·5 lb.; at 70°F.—13 lb.; at 80°F.—19 lb.; at 90°F.—25 lb.; at 100°F.—32 lb. These cylinders are so designed as to take advantage of the natural vapour pressure of the liquid. Sixty pounds of additional air pressure is also added to the cylinder before it leaves the factory. The natural vapour pressure and the additional air pressure will cause the liquid to rise through the central tube. In some type of cylinders manufactured in England there are two valves, one of which delivers vapour and the other painted red, delivers liquid. No air pressure is applied to the one pound can. Cylinders are provided with fusible safety plugs which will melt at 165°F. Cans will distort at 150°F. and burst at 185° to 190°F. So both the cans and cylinders should never be subjected to these very high temperatures. Glass sealed ampoules containing 20 c.c. of methyl bromide are also sold.

Applicators for use with cans. At any temperature above 40°F. liquid methyl bromide in 1 lb. cans is under pressure. The opening can be done with a special inexpensive device called the Jiffy can puncturer or opener (Plate VI, fig. 4). When the can is inserted into the steel band of the opener and the lever pulled, the can is punctured and the hole automatically gasketed so that the liquid flows through tubing into the fumigation chamber, box car, or other space. As the application is from outside the structure, this method provides maximum safety and even eliminates the necessity of a gas mask during the application. To enable the pressure within the can cause the liquid to flow through the tubing, the point of puncture should be the lowest point on the can but care has to be taken to see that the puncture is not made on the side seams. Special Jiffy applicators for use with cans are also

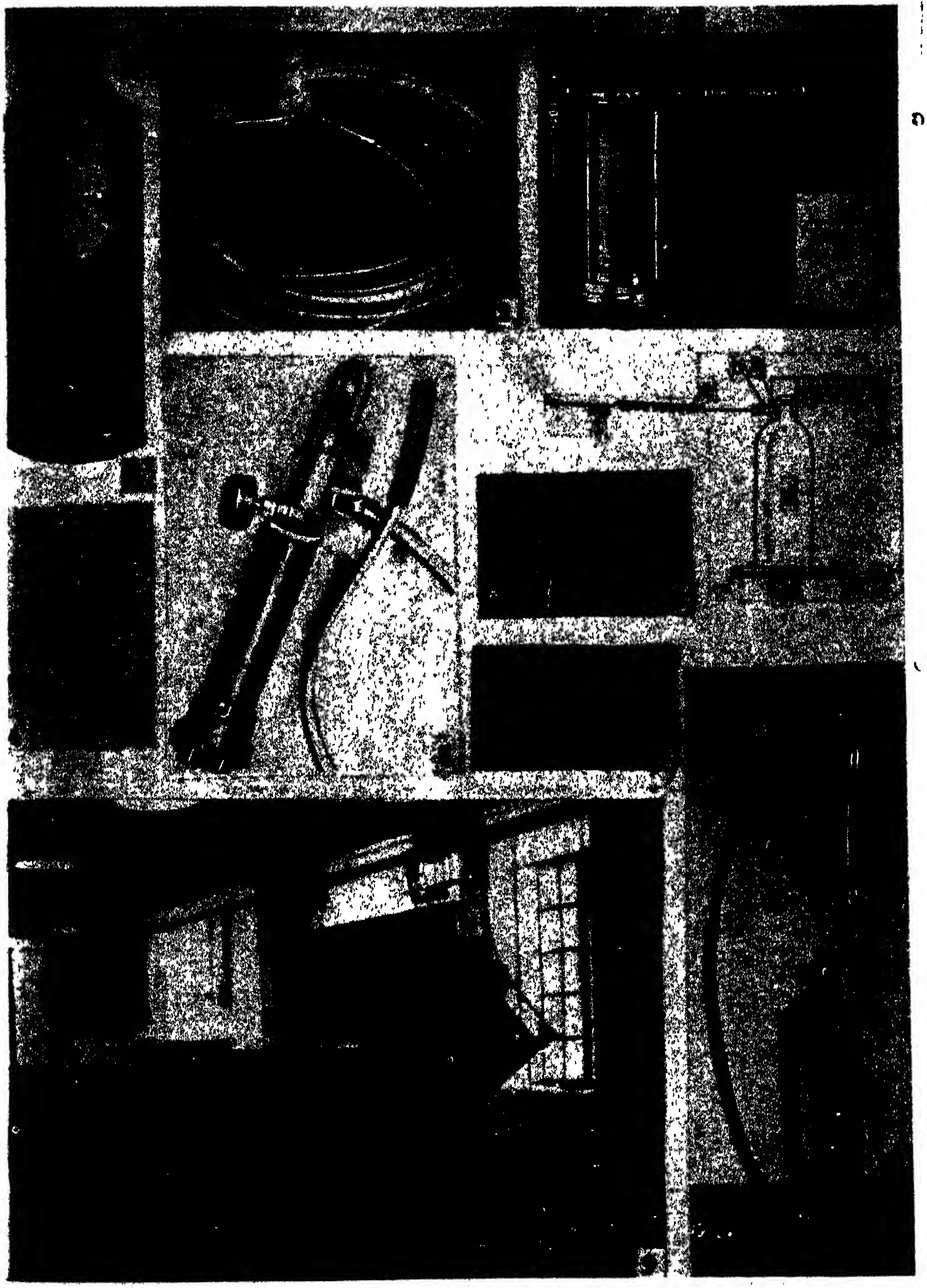
available for fumigating railway carriages and material under tarpaulins. Plate VI, fig. 2), Jiffy Fumigation Chamber Applicators (Plate VI, figs. 6 and 8) are also available. This applicator has to be screwed to the wall of the chamber by means of flange and is provided with a base to support the can. A tube extends into the chamber releasing the gas at a point above the load. For fumigation chambers in which less than one pound of methyl bromide is used for dosage, 280 c.c. applicators fitted for one pound cans have also been devised. Ordinarily, however, Plant Quarantine Stations in the U. S. A. prefer to use methyl bromide in cylinders.

Application of methyl bromide by direct weighing of cylinders. When large quantities of commodities are being fumigated and the quantity of methyl bromide used each time is several pounds, it may be measured by direct weighing of the cylinder as shown in Plate VI, fig. 7. The connections are made as follows: The cylinder (d) is placed on the weighing machine (Sc); a copper or Saran tube (e) is attached to the cylinder valve (a) by means of a reducer connection (b). If copper tubing is used it should be supported at (f) and coiled through several turns to eliminate any pulling strain on the cylinder. The cylinder is weighed carefully. The required dose having been computed, the scale is reset to the weight of the cylinder after the dose has been withdrawn. The cylinder valve is then opened and methyl bromide is allowed to flow through the tube into the fumigation chamber. When the beam tips, the valve is closed.

Applicators for use with cylinders. A number of applicators have been devised ranging in size form 100 c.c. to five pounds for use with methyl bromide cylinders. Plate VI, fig. 3 shows a 5 lb. applicator with glass calibrated in ¼ lb. steps. But similar ones are available with calibrations in steps of 1 c.c. or 2 c.c. The applicators have clamps which allow permanent fitting up on the outside of the fumigation chamber wall and a tube to connect the applicator to the chamber. The applicator is connected to the cylinder by means of a short length of copper tubing and a reducer connection. Cylinders are connected to the applicator by a single nut on the end of the reducer connection. While operating the applicator, all valves should first be tested to see that they are closed. Then the cylinder is connected to the applicator. When the cylinder connection is tight, the valve 'A' on the top of the cylinder is opened (Plate VI, fig. 3). Next the intake valve 'B' on the applicator is opened allowing the methyl bromide to enter the measuring glass through the standpipe opening at the bottom. If as it sometimes happens the flow of the liquid stops, the relief valve 'Rv' should be 'cracked' (opened for a few seconds and closed immediately) to relieve air pressure. When the proper level in the measuring glass is reached, the intake and cylinder valve should be closed. The outlet valve 'C' is opened permitting the methyl bromide to enter the fumigation chamber. As soon as the methyl bromide disappears from the measuring jar, the outlet valve 'C' is closed.

Calculation of dosage of methyl bromide. When a dosage of methyl bromide is calculated by weight the following formula is used:

Divide the volume of the vault in cubic feet by 1,000, then this quotient is multiplied by the dosage rate as expressed in pounds per 1,000 cubic feet.



EXPLANATION OF PLATE VI

FIG. 1. A Photograph of a methyl bromide cylinder. (Courtesy Dow Chemical Co.)

FIG. 2. Jiffy methyl bromide can puncturer with Saran tube. (Courtesy Dow Chemical Co.)

FIG. 3. A methyl bromide 5-pound applicator for use with cylinders of methyl bromide. (Courtesy Dow Chemical Co.) A : valve on the top of cylinder ; B : Intake valve ; C : Outlet valve

FIG. 4. Jiffy methyl bromide can puncturer. (Courtesy Dow Chemical Co.)

FIG. 5. Photograph of Frigidaire halide leak detector. (Courtesy Dow Chemical Co.)

FIG. 6. Jifty fumigation chamber applicator for use with methyl bromide can. (Courtesy Dow Chemical Co.)

FIG. 7. Diagram to show the method of application of methyl bromide by direct weighing of cylinder. *a* : Cylinder valve ; *b* : Reducer connection ; *d* : Cylinder ; *e* : copper tubing ; *f* : Support ; *Sc* : Weighing scale.

FIG. 8. Jiffy fumigation chamber applicator for use with methyl bromide cans. (Courtesy Dow Chemical Co.)

FIG 9. Photograph of a Prestolite halide leak detector. (Courtesy Dow Chemical Co.)

FIG 10. Photograph of a tank for giving hot water treatment for imported bulbs (Photograph by V. P. Rao.)

For example, for a dosage of 1·5 pounds per 1,000 cubic feet in a 1,400 c. ft. chamber it would take $1{,}400/1{,}000 \times 1{\cdot}5 = 2{\cdot}5$ lb.

When a dosage of methyl bromide has to be measured the following formula is used :

Multiply the index of the desired rate (given below) by the capacity of the vault in cubic feet.

For example, for a dosage of 2 lb. per 1,000 cubic feet in a 31 cubic feet vault, $0{\cdot}52 \times 31 = 16{\cdot}12$ c.c.

The basic index is 0·26 c.c. per cubic foot per pound per 1,000 cubic feet.

Rate per 1,000 cubic feet	Index
1 lb.	0·26
1·5 lb.	0·39
2 lb.	0·52
2·5 lb.	0·65
3 lb.	0·78
3·5 lb.	0·91
4·0 lb.	1·04

c.c. per c.ft.

Work carried out in the United States has shown that for practical purposes ½ lb. of methyl bromide per 1,000 c.ft. equals ½ hour of exposure or 10°F. difference in temperature, once a lethal dosage at any temperature is determined. If 100 per cent kill of an insect is obtained with a schedule of two lb. per 1,000 c.ft. for two hours at 80°F., a drop in temperature of 10°F., can be compensated by increasing the dosage of one half pound or by increasing the time, ½ hour. This has been found to be true in California also and can, therefore, be adopted in India too.

Fumigation of railway freight carriages with methyl bromide. Methyl bromide has always to be applied from outside the railway freight carriage by means of a copper or Saran plastic tube attached to a Jiffy can operator or methyl bromide cylinder whichever is being used. Duplicate can applicators should be available in case of breakage. The tube has to be introduced into the carriage through a hole drilled in the floor near the centre of the carriage or through any other convenient opening. The discharge end of the tube should be attached at the centre of the carriage near the ceiling by propping up the end of the tube. The opening of the tube has to be plugged and a hole drilled laterally allowing the mist of the methyl bromide towards the opposite ends of the carriage. As the Saran plastic tubing becomes a little brittle when cooled to about 32°F. it should be examined now and then to prevent gas leakage from it.

For obtaining best results in fumigating railway freight carriages, very great care has to be taken to thoroughly check for all possible leakage points and all these should be sealed with masking tape, caulking compound, bug putty, or strips of greased paper. An excellent caulking compound can be prepared by mixing 8 parts of asbestos, 3 parts of calcium chloride and 4 parts water by weight. As in Canada, brown paper liberally smeared with a good quality casein paste can be used. A paste made by adding lubricating oil to flour and mixing it to a putty-like consistency may also be used. In the U. S. A. special masking tapes manufactured by Minnesota Mining and Manufacturing Co., St. Paul (Minnesota) or the Industrial Tape Corporation, Chicago, (Illinois) are used. Heavily oiled kraft gummed tape can be used for surfaces on which it sticks well. Special attention has to be paid to the openings near the doors, and around the rollers of the door tracks.

Although it is safer for the operator to use a gas mask, it is not very necessary since methyl bromide is applied from the outside of the carriage. It has been found that one pound cans of methyl bromide are very convenient for fumigation of freight carriages. At first the cubic capacity of the freight carriage has to be ascertained and the dosage calculated according to the commodity to be treated. The application of the fumigant is made as follows :

The tins are clamped one at a time, in the Jiffy puncturing device fastened to the end of the tube. The puncturing has to be done as close to the bottom of the can as possible avoiding the soldered seam. As soon as the can is punctured the methyl bromide will leave the can under its own vapour pressure. A can will be emptied in less than 60 seconds and the methyl bromide will be discharged in the railway freight carriage as a fine mist changing immediately into vapour.

The actual application of the gas can be done by the operator standing on the ground by the side of the carriage or from the top of the carriage. In the latter case the can applicators are mounted on a small wooden platform to keep steady the cans against the back pressure of the gas.

When a methyl bromide cylinder is used, the copper or Saran plastic tube should be attached to the cylinder valve. The dosage should be measured by a weighing on a portable platform scale. No attempt should be made to release the methyl bromide in open carriage and then commence closing the doors and sealing. 10 to 15 lb. of methyl bromide with an exposure period of 10 to 18 hours would be required to fumigate a railway carriage (steel carriages of good construction may need only six to eight hours). As a safety measure to prevent persons from entering a carriage under fumigation, prominent warning signs should be pasted on both the doors before methyl bromide is applied.

At the completion of the fumigation period, both carriage doors should be opened from the outside to permit aeration. No one should be allowed to enter the carriage for at least half an hour. It is safer to find out whether aeration is complete or not by using a halide leak detector.

Fumigation of railway carriages should be carried out as far as possible in isolated yards far away from human habitation. If a large number of carriages have to be

fumigated it would be advantageous to segregate the carriages undergoing aeration on another track so that fumigation operators are not exposed to the gas emerging out of the carriages undergoing aeration. No hard and fast rule as regards the period of aeration can be made as it depends on the climatic conditions and air currents, but ordinarily six hours of continuous aeration may be necessary before the carriages are released for despatch for destination.

Fumigation of fruit in freight or refrigerator carriages with methyl bromide. It may often be necessary to fumigate fruit in railway freight carriages on the Indo-Pakistan border.

The procedure mentioned in the previous chapter may be used with success but the following additional precautions would have to be taken.

1. Under no circumstances should fumigation be attempted on chilled fruit or when ice is present in the bunkers.

2. Fumigation should not be attempted at temperatures below 65°F. or in excess of 95°F.

3. Bunker drains should be properly sealed and plugged to prevent leakage. The carriages must remain stationery during fumigation. All plugging and sealing should be removed at the end of fumigation.

4. The schedule for use in treating fresh packed pears in refrigerated carriage in the U. S. A. for the control of codling moth eggs and larvae has been found to be the application of 4 lb. of methyl bromide for an exposure of two hours.

5. Injection should be effected by means of a $\frac{1}{4}$ in. copper tube leading to the upper centre of the carriage well above the packed fruit or in the bunkers with the load divided one half to each end of carriage. Care should be exercised in placing the tube outlets so that the methyl bromide does not directly spray on the fruit. The end of the tube should be wrapped with a roll of rags or gunny and placed in an empty box held in the upper centre of the bracing of the carriage.

6. Both during injection and for a period of at least 10 minutes following, fans of not less than 10 in. diameter should be operated one at each end of the carriage. Following the completion of the two hour exposure, doors as well as all bunkers should be opened completely and allowed to aerate for a period of at least one hour before the carriage is iced.

7. Exposure should be for *two hours* only.

Fumigation of fruit under tarpaulins. Rubberized sheets have been found suitable for fumigating stacks of fruit boxes. The best tarpaulin for such a purpose is a light duck fabric coated heavily on one side with a plastic material impervious to methyl bromide gas. The reverse side is covered more lightly. Types of fabric treated with oil should never be used, as methyl bromide is an oil solvent. This type of fumigation under tarpaulin should be accomplished in the shade or at night. Boxes should be stacked not more than six feet high and arranged in a rectangular stack. Under no circumstances should chilled fruit be placed under fumigation. Fruit should

not be stacked and fumigated where direct sunlight strikes the tarpaulins. Fumigation should not be carried out at temperatures below 65°F. or in excess of 95°F. The stacking of the fruit boxes should be done in such a way as to provide two open aisles of about one foot width in the form of a Greek cross, extending through the entire length of the stack in opposite directions. This arrangement will facilitate gas diffusion. The stacks should be made on a gas tight floor, concrete or earth being preferred. Two electric fans of not less than 10 in. in diameter should be in operation on the floor at the two extremeties of one of the aisles one pointing towards the other in an upward direction. Fan operation should continue during injection and for a period of ten minutes following. Injection of methyl bromide can be made either from a large high pressure cylinder equipped with a proper measuring device or from one pound cans dispensed from approved applicators. In either case injection is made with the help of a $\frac{1}{4}$ in. copper or plastic tubing. The end of the tube should be wrapped tightly in gunny or rags and placed in an empty box at the upper centre of the stock. A number of empty boxes placed at the corners and edges of the stack and some at random on the top will hold tarpaulin above the fruit and create on air dome permitting better diffusion of the fumigant. Tarpaulin edges will have to be properly weighed down with 'sand snakes' or saw dust sacks to prevent leakage. Exposure to methyl bromide should be only for two hours.

Fumigation of plant material with methyl bromide. Ordinarily, temperature conditions in India will be suitable for fumigation of plants except in some parts where there are extremes of temperatures. In cold weather it would be necessary to warm the plants and any earth balls which may accompany them. This has to be done to avoid the need of using very high dosage schedules that would be necessary to kill insects completely at low temperatures. Two hours are usually sufficient to secure complete kill of insects.

Higher temperatures within certain limits increase the kill of insects and plant tolerances are not affected greatly until temperatures approach 90°F. At lower temperatures the resistance to the fumigant of both the insect and the plant increases. Plant tolerance for fumigation and higher temperatures are greatly increased during dormancy. So the best results in fumigation have been obtained in the case of dormant plants. Insect resistance for fumigation varies both with the stage of the insect and its location in or on the plant. For example some borers and miners are difficult to be killed.

Plants to be fumigated with methyl bromide must be moist. High humidity both during the conditioning for treatment and during the treatment tend to minimize plant injury. A wet gunny or a basin of water is therefore placed in the chamber in some plant quarantine stations.

Fumigation is best done at temperatures between 80° and 85°F. Balled plants should never be fumigated until the cut surfaces of the roots have had a chance to form a callus. This might require about ten to fourteen days. Conifers should be treated only during the dormant season. Fumigated plants drop their leaves but this is followed by a prolific flush of new growth. The method of loading a chamber is very important in fumigation of plants. Double decking of plants in

cans or balled plants should not be done as efficiency of the fumigant is reduced. In fumigating tender plants such as ferns, succulents, orchids and some palms, the velocity of the air current should never be so strong as to cause whipping and thereby injuring the plants.

Fumigated plants should be given proper airing and be protected against direct sunlight and dry winds. They should also be properly watered.

Fumigation of grain using methyl bromide. Procedures in warehouse fumigation using methyl bromide have advanced considerably in the U. S. A. Methyl bromide cylinders are used generally in such cases and the gas is released in the rooms by operators wearing gas masks and working inside the fumigation space. In England this method of fumigation is forbidden. Similarly in the early stages of the introduction of the gas for fumigation in India, it may be safer to undertake it with the operation being carried from outside the space to be fumigated. As India imports large quantities of food grains from abroad and there are great chances of importation of grain pests not so far found in this country, some method of fumigation of the imported grain is very necessary. The tarpaulin method of fumigation may be preferred if regular large fumigation chambers are not available. Tarpaulin fumigation should however never be attempted in a closely confined space. An open space should be preferred so that the gas can escape quickly following fumigation. The preliminary procedures are similar to those described for tarpaulin method of fumigation of fruit. The bagged grain which is usually stacked irregularly will have to be re-arranged properly, in a square area up to a height of about 5 or 6 ft. The flooring may preferably be of earth, concrete or other airtight surface free from cracks. A few bags should be stacked upright on the top of the whole pile to form a sort of dome. The exit end of the copper or plastic tubing leading from the methyl bromide cylinder or the can should be placed near the centre of the dome in such a way that the gas does not come directly into contact with the tarpaulin. The latter should be placed over the stack taking special care to leave two or three feet margin trailing on the floor. The sealing is done by laying sand bags or ' snakes '. The application of the required quantity of the gas may be done by placing the cylinder on a platform scale as already explained on page 324. Ordinarily 1 to 1½ lb. of methyl bromide per 1000 c.ft. of estimated space under tarpaulin are recommended for agricultural seeds and bagged grain. The exposure period should be 12 hours at a temperature above 60°F. In the case of finely divided products like flour, the exposure period should be extended to 18 hours. At the end of the fumigation period the tarpaulin should be partially pulled back from the fumigated material and the latter allowed to air for about an hour. The tarpaulin can then be entirely removed. Another half an hour should elapse for the fumigated material to be removed.

In the case of stored grain pests in rice bags atmospheric fumigation using 1 lb. of methyl bromide for 1000 c.ft. for 12-24 hours or vacuum fumigation using 3—4 lb. of methyl bromide for 1000 c.ft. for 3 hours, the gas being injected in a 27 in.—28 in. mercurial vacuum, is recommended. In the case of stored grain pests like *Tribolium confusum* (Confused flour beetle), *Tenebroides mauritanicus* (Cadelle), *Acanthoscelidus obtectus* (Bean weevil), *Ephestia kühniella* (Mediterranean flour moth), *Sitotroga*

cerealella (Angoumois grain moth), *Plodia interpunctella* (Indian meal moth), etc. attacking milled cereals of various kinds, wheat , maize and other grains, atmospheric fumigation using 1—1·5 lb. of methyl bromide for 1000 c. ft. for 12—24 hours and vacuum fumigation using 1 to 2 lb. for 2—4 hours, the gas being injected in a mercurial vacuum of 27 in. --28 in. is recommended.

As regards maize and wheat for germination, the moisture should not exceed about 12 per cent and the fumigation period should not exceed the maximum limit. Bagged grain, etc. should not exceed depth of 30 ft.

Ship and barge fumigation with methyl bromide. The use of methyl bromide in ship and barge fumigation is fairly recent. In the case of ship fumigation the preliminary procedures are the same as those described under ship fumigation with HCN gas. Section of the ship which has to be fumigated, should be sealed off very carefully. The rate of methyl bromide to be applied is two pounds per 1000 c.ft. The temperatures should be above 60°F. for this dosage and the exposure period should be 24 hours. In the U. S. A. for fumigating parts of ships methyl bromide cans have been used with success, the application of the gas being done making use of the Jiffy chamber applicators as shown in Plate VI, figs. 6 and 8 but the methyl bromide cylinders will be equally good. In the case of holds of ships, care must be taken that the cargo is stacked carefully with space or an aisle between rows of stacks of boxes or sacks, etc. so that the gas diffuses and circulates properly and enables it to penetrate the sacks. Electric fans should be placed some on the top of the cargo and some on the floor so that the gas circulates properly and to prevent its stratification ; these fans must be operated for about half an hour following application. The aeration period at the end of fumigation should be at least 12 hours. It is safer if tests with halide detectors are made for small concentrations of the gas before finally entering a fumigated space.

Fumigation of barges with methyl bromide has been found to be easier and very effective and is therefore used considerably in England and Canada. In the case of wooden barges considerable sealing of all leaks would be necessary to prevent leakage of gas but in the case of steel barges a thick rubberized tarpaulin on the top of the hatches battened as for sea, is sufficient. The dosage is 2 pounds per 1000 c.ft. at a temperature above 60°F. the exposure period being 24 hours. In the case of barges. aeration is quicker. As in the case of the holds of ships, the cargo must be stacked properly with space between rows of stacks. some space on the sides and on the top between the stack and the tarpaulin. Methyl bromide cans or cylinders can be used. When the latter is used, the entire fumigation equipment can be placed on the top deck or on another barge. If the barge to be fumigated is by the side of the pier, the fumigation equipment can also be placed on the pier. A long plastic (Saran) tubing has to be used to eject the gas to the top of the barge when released from the cylinder.

The method described above can also be used with success in the case of schooners as well as freighters. In the case of freighters having more than one hold, to obtain good results and conduct the fumigation successfully, it is necessary to see that the

gas circulates to all parts. To make this possible the copper tubing leading from the methyl bromide cylinders to each of the hold must by means of T connection be divided into two lines leading in opposite directions and each of these again has three final outlets. Use of pallet boards on which the cargo is placed, has been found to be very helpful in facilitating the circulation and penetration of the fumigant throughout the cargo. If freighters to be fumigated have elevators, their platforms should be left at the bottom of lower holds. Two fans should be used for each hold to circulate the gas and they will have to be operated for 30 minutes. The dosage and the period of exposure is calculated in the same way as in the case of barges. Great care has to be taken for the process of aeration of freighters at the end of treatment period of 24 hours. The operators wearing gas masks must at first remove only a couple of boards at each side of the hatch covers. Then at intervals of 30 minutes, more boards should be removed and by about eight hours all the hatches be completely uncovered. Halide detectors may now be used to see if there are traces of the gas and if found free from gas the operators still wearing gas masks can now enter the 'tween-decks and open all side doors of the hull from the inside. Then the port holes in cabins and crew quarters should be opened. The aeration of freighters of the ocean going types would be very difficult. In some cases atmosphere safe for human occupation has been found to reach only 68 hours after aeration began. This period may considerably be reduced if some arrangements are made by providing suitable ducts for drawing out high gas concentrations from the interior parts of the holds. Much work on this subject has still to be carried out.

Detection of the gas. In methyl bromide fumigation, greatest care has to be taken to see that there are no leaks in the chamber or in the applicator. Leaks can be detected by a halide leak detector. Cylinders of methanol (wood alcohol) or acetylene are used for fuel in these detectors and the flame passes through a copper disc. The presence of methyl bromide is indicated by the progressive change in colour of the flame from violet through green to a vivid blue depending upon the amount of bromide present (as indicated in the list given below) when the sampling tube of the halide detector is placed in air containing methyl bromide. These halide detectors are commonly used in checking gas leaks in refrigeration equipment.

Methyl bromide present—parts methyl bromide per million	Pounds of methyl bromide per 1000 c. ft.	Flame colour
0	0	Almost invisible
40	·010	Rather faint green
60	..	Moderate green
100	·024	Moderate green
130	·031	Strong green; slightly blue at edges
180	·043	Strong green ; rather blue
240	·058	Strong blue-green
360	·086	Strong blue-green
800	·192	Strong blue

Two types of halide leak detectors are available in the U. S. A. One is called the Prestolite halide leak detector (Plate VI, fig. 10) and the other is Frigidaire halide leak detector (Plate VI, fig. 5). Prior to using the detector, care has to be taken to clean its throat. Only when the flame is strong and it comes out direct through the centre of the cone of the torch, that the latter will become red hot and if the flame spreads around the cone, it will not heat properly and often a green colour appears even in the absence of any halide. Should this happen, the torch has to be put out, cooled, cleaned and then relit.

The 'Just—Rite' halide detector burning petroleum ether, the Tilley lamp burning paraffin and the Bladon burning alcohol are used in Britain for detection of methyl bromide. Amongst these, the Tilley lamp is considered to be more sensitive and gives a slightly coloured flame with air containing 8 p.p.m. and a distinct colouration at 16 p.p.m. of methyl bromide. Whichever of the above mentioned five lamps are used, the operator must make himself thoroughly familiar with its performance in known concentrations before relying on its readings to enter an area after fumigation.

Protection of operators using methyl bromide. Methyl bromide has to be handled carefully. Although dispensing equipments have been developed eliminating exposure and assuring maximum safety to the operator greatest caution should be observed when using it. Continued exposure even to low concentrations of the gas has to be avoided. Operators should use approved gas masks when exposed to the gas during fumigation. The mask prescribed for it is one equipped with a black canister type B for organic vapours, approved by the United States Bureau of Mines. Manufacturers' instructions given on the canisters must be closely followed by the operators. The masks should neither be used in known concentrations of the gas stronger than the limit mentioned on the canister nor for total exposure period longer than the recommended, as the life of the canister depends on the time in use and upon the concentration of the gas. The limitations of the mask and the canister must be known to the operator. Gas masks and canisters approved by the U. S. Bureau of Mines are made by the following firms in the U. S. A.

Manufacturer's name	Type	Canister
Mine Safety Appliance Co.	AB	GMA.
E. D. Bullard Company	CM	CM—1
Davis Emergency Equipment Co.	M—L	C—L

'Purethka' masks supplied by Siebe Gorman & Co. are used in England.

Symptoms of methyl bromide exposure. Operators exposed to methyl bromide show very little or no symptoms of exposure at first. These come on gradually after several hours after inhalation of the gas. The symptoms are : (i) dizziness, (ii) blurred vision, (iii) sensation of fatigue, (iv) staggering gait, (v) slurring of speech,

(vi) nausea and vomiting, (vii) loss of appetite and (viii) abdominal pain. Overwhelming exposure results in difficult breathing. In case of exposure to the gas, the patient should be immediately taken into fresh air and given artificial respiration. A physician should be immediately sent for. The patient should be kept in a sitting or reclining position. Care must be taken to see that he does not fall or strike against anything. He must be kept comfortably warm, if necessary covered with blankets.

In experiments made on animals, it has been found that continued exposure to low concentrations of the gas causes paralysis ; but they have been found to recover when removed away from the environment of the gas. Exposures to higher concentrations have resulted in lung irritation which can become acute and severe after developing into typical confluent broncho-pneumonia. However, when exposures are irregular and at intervals of several days, the effects can be thrown off by the animals. In man slight exposure to the gas has been found to cause weakness, vertigo and dyspnoea. In more severe exposures there may also appear psychic disturbances, attacks of mania and transitory brachial paralysis. Double vision, amblyopia and aphasia have also been noted in certain non-fatal cases. In France, severe fatal poisonings as the result of inhalation of the gas while filling fire extinguishers have been reported. In the U. S. A. the two fatalaties and several less severe cases resulting from exposures during fumigation have been reported. Liquid methyl bromide when spilled on the skin causes burning.

Only experienced and trained staff should be permitted to handle liquid methyl bromide. Toxicity of the gas has been underestimated owing to ignorance of its toxicity when used as a fumigant as well as its lack of odour at the lower concentrations and the fact that it possesses no irritant properties. Although the gas is less deadly to man than certain other fumigants in common use in countries like the U. S. A. it has been found that careless handling and inadequate protective measures will unduly expose fumigators and other persons coming in contact with the fumigant. It is therefore recommended that all the precautionary measures issued in connection with the use of the gas should be closely adhered to.

The Division of Industrial Hygiene of the National Institute of Health, U. S. Public Health Service in 1938 made the following preliminary recommendations :

1. Avoid breathing air containing methyl bromide.
2. On completion of fumigation, provide thorough ventilation for cars, rooms or buildings before entering.
3 When necessary to enter space containing methyl bromide, use a gas mask provided with a canister giving protection against organic vapours, or a positive pressure hose mask (masks and canisters to be approved under the U. S. Bureau of Mines Schedules 14 D or 19 A. Canister black, type B).
4. Avoid spilling of methyl bromide. Get to fresh air immediately in case of spillage. Remove any clothing in contact with the skin which has become impregnated with the liquid.

5. Post warning signs, notifying that methyl bromide is being used and that the gas is toxic.
6. Containers of methyl bromide should be stored in a cool, well-ventilated place, outside inhabited buildings. Avoid leakage by seeing that valves of cylinders are tightly closed.

Contact of liquid methyl bromide or high concentrations of its vapour with the skin may lead to the formation of blisters, or an eczematous skin. The parts which have come in contact with methyl bromide should be thoroughly washed immediately with plain water or preferably water to which a little washing soda is added. If blisters have appeared they should be dressed with propamidine cream or with 2 per cent tannic acid in triple dye solution. They can also be covered with a mixture of sulphathiazole, magnesium oxide and calcium penicillin under tulle gas. Chlorbutal ointment may be used to relieve pain.

In cases of systematic poisoning medical aid should be arranged. The first aid kit recommended in England includes oxygen-carbon dioxide reviving apparatus and Leptazol ampoules with injection equipment. According to published literature adrenaline should not be administered; ammonium carbonate may be given in the hope of decelarating vascular damage ; the carrying out of lumbar puncture is suggested as an aid to diagnosis.

Below is a list of commodities and the dosage of methyl bromide for fumigating them as successfully used in the U. S. A. at approximately 70°F. in shade. At temperatures about 80°F. on commodities easily penetrated, the time of exposure may be decreased proportionately. Much work has to be done in India on various commodities that require fumigation.

TABLE I

List of commodities treated with methyl bromide in the U. S. A.

Commodities treated	Method of treatment	Pounds per 1000 c.ft.	Time of exposure	Remarks
Dried beans and peas	Atmospheric	1·0 to 1·5	15 to 24 hours	
Dates (loose)	Atmospheric	1·0 to 1·5	15 to 24 hours	
Dates (compress packed)	Vacuum 25 in. to 29 in. sustained	2·0 to 3·0	1·5 to 3·0 hours	
Dried fruits	Atmospheric	1·0 to 1·5	15 to 24 hours	
Hay (baled)	Atmospheric	2·0	12 to 24 hours	
Nuts (whole or shelled)	Atmospheric vacuum 25 to 29 in. sustained	1·0 to 1·5 2·0 to 3·0	15 to 24 hours 1·5 to 3·0 hours	

TABLE I—*contd.*

List of commodities treated with methyl bromide in the U. S. A.

Commodities treated	Method of treatment	Pounds per 1000 c.ft.	Time of exposure	Remarks
Packaged foods, flour, cereals, spices, etc.	Atmospheric vacuum 25 to 29 in. sustained	1·0 to 1·5 2·0 to 3·0	15 to 24 hours 1·5 to 3·0 hours	
Plants and dormant nursery stock	Atmospheric vacuum	0·5 to 2·0 2·0 to 3·0	2·0 to 8·0 hours 1·5 to 3·0 hours	Must be varied according to the pest and host
Potatoes, tomatoes, pears, apples and green vegetables in general	Atmospheric	2·0	2·0 hours	
Potatoes	Vacuum 27 in.	2·0 to 3·0	1·5 hours.	
Textiles, bedding, furniture, etc.	Atmospheric vacuum 25 to 29 in. sustained	1·0 to 1·5 2·0 to 3·0	15 to 24 hours 1·5 to 3·0 hours	Rubber or rubberized materials should not be fumigated with methyl bromide
Wheat, rice, barley, corn and seeds in general	Atmospheric	1·0 to 1·5	12 to 24 hours	Methyl bromide has no deleterious effect on germination when used under normal conditions
Coffee (dried)	Atmospheric	1·5	12 hours	
Bagged grain like rice or other commodity of similar particle size	Atmospheric	3 2 1	4 hours 6 hours 12 hours	
Flour and returned flour bags	Atmospheric	1 1·25 2	24 hours 18 hours 12 hours	1·25 lb. for 18 hours is considered optimum

Ethylene oxide

Ethylene oxide is a colourless liquid at low temperatures. It boils at 10·7°C., has a specific gravity of 0·887 at 4°—7°C., molecular weight 44·031 and vapour pressure at 0°C., 493·1 mm. Its freezing point is 140°C. At 77°F. 112·5 pounds of the gas are required to saturate the atmosphere of 1000 cubic feet of space. At ordinary temperature it is a gas which is 1½ times as heavy as air. It has a rather faint odour suggestive of ether. It is inflammable in concentrations between 3 per cent and 80 per cent. But due to its excellent toxicity to insects particularly those attacking stored grain, the ease with which it can be handled, and the fact that it

leaves no odour or undesirable residue on foodstuffs, its use has been quickly adopted for the fumigation of several commodities. Moreover by mixing carbon dioxide with ethylene oxide, the insecticidal action of the gas is increased while the fire hazard is reduced. It is therefore now marketed in the U. S. A. as a mixture of one part of ethylene oxide to nine parts of carbon dioxide in steel cylinders for use in atmospheric as well as vacuum fumigation. It is available under various names like Carboxide, Guaradite · gas, etc. and is supplied, in 60 lb. cylinders under lb. per sq. inch pressure. In Germany a similar mixture is marketed under the name 'Cartox'. Although in actual practice it has been found that it is sufficient to use mixture of ethylene oxide and carbon dioxide at rates not higher than 1 : 10 —1 : 15 but not less than 1 : 7·5 in view of the inflammability of the ethylene oxide, in England and Germany, mixtures composed in the proportion of 90 per cent ethylene oxide and 10 per cent carbon dioxide are also used. In Germany such a mixture is called the T-gas and in England it is sold commercially in steel cylinders under the name of 'Etox'. It is diffused by means of flexible copper tubes through a fine jet. On exposure to air, ethylene oxide vaporises with rapidity. Even at low temperatures it can be used successfully on account of its low boiling point. It readily mixes with water, alcohol, acids and ammonia. It is less toxic than hydrogen cyanide but more toxic than carbon tetrachloride or sulphur dioxide being 250 times more toxic than the latter substance. Its insecticidal action is similar to that of methyl bromide. It has a delayed killing effect, is highly effective against insects eggs and about the same relative toxicity to insects in the adult stage. The post-fumigation effect of the mixture of ethylene oxide and carbon dioxide has however been found to be less than that of HCN in the case of Tobacco beetle. It will not bleach materials and is highly penetrative.

In spite of its efficiency as a fumigant, the cost of transporting the heavy cylinders of the gas makes it difficult to compete against some of the other effective fumigants like methyl bromide. Its manufacture has, therefore, been considerably reduced.

Directions for applying ethylene oxide. The fumigating chamber is at first loaded and made ready for fumigation. If small quantities of the liquid are to be used they can be drawn off by gravity flow into a tall glass jar, weighed or measured as is considered necessary and then poured directly into a shallow pan placed in the fumigating chamber. As the liquid is highly volatile at ordinary temperatures, its handling when transferring it into the pan should be done with speed. When large quantities of the liquid ethylene oxide are used for commercial fumigation, the required amount of the liquid should be first drawn into a graduated applicator similar to the one described for methyl bromide. The applicator is connected with the chamber by means of a metal tubing so that by opening a valve the measured quantity of the liquid is allowed to be drawn into the fumigation chamber. The temperature of the material to be fumigated should be between 75° to 78°F. In vacuum fumigation, when the ethylene oxide and carbon dioxide mixture like 'Guardite gas' is used, it is expanded to 75 lb. per square inch pressure in an

accumulator and heated to 120°F. to insure its entering the treating chamber in gaseous form.

Fumigation of grain. The most important use of the gas is for fumigating grain in bins. For this ethylene oxide mixed with solid carbon dioxide in the form of 'dry ice' can be used effectively although the process is expensive and laborious. Three pounds of liquid ethylene oxide and 30 pounds of carbon dioxide per 1000 bushels of grain are used. The mixture of the chemicals is made in the following way. The solid carbon dioxide is placed into an open end box and broken into small pieces with a sledge spade or ice pick. Ethylene oxide is then poured over the dry ice pieces in the proportion of 1 pound to each 10 lb. of the solid carbon dioxide. For quickly measuring out the required quantity of the liquid ethylene oxide, the cylinder can be weighed on a platform scale and the liquid forced out by air pressure created by a cycle pump. The mixture has to be stirred well so that the 'dry ice' takes up all the liquid. The mixture moreover has to be prepared just before use and taken to the bin floor where it should be immediately applied by shovelling into the grain stream as it is entering the bin. The mixture of the chemicals then becomes thoroughly distributed and mixed with the grain and soon changes to a vapour killing all insects which are present. In the U. S. A. to counteract leakage the dosage for the first 1,000 and the last 500 bushels is made proportionately greater and that for the rest of the grain reduced, so that the average of 33 lb. per 1,000 bushels is preserved.

According to the method adopted in the U. S. A. for bin fumigation, the person applying the fumigant will naturally have to inhale the gas, smaller quantities of which are not harmful. Prolonged exposure to the fumes should however be avoided as it is likely to cause severe nausea.

In Germany 'Cartox' is widely used for fumigating grain silos. The gas is however supplied only to authorized persons and is delivered compressed in cylinders of about 55 lb. capacity. Equipment is provided for air to be extracted at the top of the silo, mixed with the fumigant released from the cylinder and then blown into the bottom of the silo so that it passes upwards through the grain. On an average 18 oz. of 'Cartox' have to be used per ton of grain.

In the U. S. A. a dosage of 1 lb. per 1000 c.ft. for 20 hours has proved 100 per cent lethal to the Rice weevil (*Sitophilus oryza*) the Indian meal moth (*Plodia interpunctella*), the Saw toothed grain beetle (*Oryzaephilus surinamensis*) and the flour beetle (*Tribolium confusum*). But for commercial fumigation of warehouses the fumigant should be used at the rate of 2 lb. per 1,000 c.ft. of space.

In England for warehouse fumigation, the normal dosage of 'Etox' used is 10 to 12 oz. per 1,000 c.ft. for 24 hours. In the case of densely packed grain, larger quantities will have to be used.

Rice can be treated with ethylene oxide either in bulk, in sacks or in sealed cartons. As rice does not absorb much of the gas, comparatively small amounts of the fumigant are effective against the insects that attack it. Fumigation of bulk rice is easier than rice in sacks and specially the cartons as more gas will be required to penetrate the tightly sealed cartons. As in India rice is generally kept in sacks

or in straw packing, its fumigation is not difficult, disinfestation being possible using one lb. of ethylene oxide per 1,000 c.ft. of space during overnight fumigation in atmospheric fumigation chambers. In vacuum fumigation, ethylene oxide should be used in the proportion of three pounds per 1,000 c.ft. for one hour, or pounds per 1,000 c.ft. for two hours. When used in combination with carbon dioxide, 2 lb. of ethylene oxide per 1,000 c.ft. for ½ hour, or 1 lb. per 1,000 c.ft. for ¾ hour, is sufficient for the treatment of bulk rice. Vacuum fumigation of bulk rice can be done in special chambers set on the end. The rice can be run into the chamber at the top and after fumigation it is drawn off through a valve at the bottom. The use of this method considerably reduces the cost of handling.

Dried beans of all kinds either loose or in bags can be fumigated with ethylene oxide. In atmospheric fumigation 2 lb. of ethylene oxide per 1,000 c.ft. of space, for an overnight exposure will kill all weevils present whether the beans are in bags or in bulk and in vaccuum fumigation 3 lb. of ethylene oxide alone per 1,000 c.ft. for one hour, or 2 lb. of ethylene oxide per 1,000 c.ft. for two hours will give a perfect kill. In combination with CO_2 it would be necessary to use 2 lb. per 1,000 c.ft. for ½ hour or 1 lb. per 1000 c.ft. for one hour.

Fumigation of barges with ethylene oxide. Fumigation of dried fruit arriving at a sea port can be conveniently carried out in steel barges using ethylene oxide as the fumigant. To enable proper distribution of the gas, the stacking of the fruit boxes should be carefully done. They should be placed in sing tiers two to three inches apart and run transversely across the barge. The boxes should not be stacked nearer than 15 inches to the hatch covers. An open passage about 4 ft. wide should be left running along the centre of the barge to within three or four tiers of the ends. Every box must have its two ends exposed to the free space. The hatches must then be closed by its wooden covers and these in turn covered by heavy tarpaulins. The edges of the latter will then have to be clamped to the hatch coamings by means of battens wedged in cleats. In barges which are kept in good condition, ordinarily the leakage can only be through the hatch openings. The application of the fumigant is done in the following manner. Ethylene oxide containing 10 per cent carbon dioxide in cylinders is used for this purpose. A copper pipe 3/8 inch in diameter from the cylinder valve has to be led into the barge and terminating in a T-piece, the two branches of which are about 15 in. long being directed one towards each end of the barge. The T-piece and its two branches will have to be raised on boxes about two feet above the boxes on each side of the passage. The exit ends of the two branches of the T-piece are fitted with nozzles through which the liquid is ejected as a fine spray under pressure from the cylinder. The fine spray is formed from two axially rotating jets which are ejected through an orifice of 0·05 inch in diameter. The nozzles will have to be dismantled, cleaned frequently and adjusted to deliver equal volumes of liquid at equal pressure. At temperatures below 50°F. a vaporiser has to be used but such a contingency rarely arises in India. The dose of the fumigant to be used assuming that it contains 85 per cent of ethylene oxide is calculated at the rate of 1 lb. for every 50 boxes of dry fruit being approximately 1¼ tons and 6·5 lb. per 1,000 c.ft. of free space. The fumigation should last 18 hours.

Fumigation of dried fruit. Dried fruit in bulk or in cartons can be fumigated easily with the gas using a dosage of one pound of ethylene oxide per 1,000 c.ft. for 12 hours in atmospheric fumigation in an airtight chamber. If the chamber is not quite airtight 2 pounds would have to be used per 1,000 c.ft. If vacuum fumigation is carried out, 2 lb. of ethylene oxide per 1,000 c.ft. for 1½ hours, or 3 lb. per 1,000 c.ft. for one hour are sufficient to disinfest dried fruit both in bulk and when packaged. In combination with CO_2, 2 lb. per 1,000 c.ft. for 1½ hours are sufficient.

Fumigation of nut meats. As nut meats like shelled, raw groundnuts, almonds, etc. absorb a much larger amount of gas than most other foodstuffs, a greater dosage would be necessary to destroy insects in them. A dosage of 3 lb. of ethylene oxide per 1,000 c.ft. for an overnight or 16 hour exposure would be required in atmospheric fumigation. If used in combination with CO_2 only, two pounds per 1,000 c.ft. are sufficient. In vacuum fumigation a dosage of 3 lb. of ethylene oxide per 1,000 c.ft. in combination with 28 lb. carbon dioxide is most suitable. For fumigation of nut meats the dosage is considered to be the best and effective.

Fumigation of fresh fruit and potatoes with ethylene oxide. This gas is reported to have been successfully used in the plant quarantine stations of France for fumigating fresh fruit particularly apples, against the introduction of the San Jose Scale. Fumigation for 1½ to 2½ hours with the gas at the rate of 100 gm. per c. m. (i.e., 10 oz. per 100 c.ft.) under a partial vacuum of 50 mm. (1·97 in.) after an initial vacuum of 635 mm. (24·9 in.) has been found to be effective against San Jose Scale and other diaspine coccids on apples without injuring the fruit under treatment. Effective control of larvae and adults of *Leptinotarsa decemlineata* Say (Colorado potato beetle) was also obtained by fumigation of infested potatoes using 30 gm. per c.m. for an hour under vacuum of 50 mm. But work carried out in other countries has shown that the gas is injurious to fresh fruit, in some cases rotting commencing about 10 days after fumigation. The use of methyl bromide has therefore now practically replaced the use of this gas. In India ethylene oxide has therefore to be used with great caution for fumigating fresh fruit and potatoes and better be avoided. It can however be used for fumigating dried vegetables. The dosage is 120 gm. per c. m. for two hours or for six hours with 100 gm. in a vacuum of 60 mm. (2·36 in.) with an initial vacuum of 700 mm. (27·56 in.).

Fumigation of books and records. Ethylene oxide has been used with great success against insects attacking books, valuable records and documents. The gas is used in all the libraries and National Archives in several countries. Ethylene oxide and carbon dioxide mixture and vacuum method of fumigation is made use of in all such cases. The books, records, etc. are placed in a vacuum chamber and the air in the latter is evacuated till the vacuum gauge registers 29·9 inches of vacuum. The gas is then introduced and the vacuum is allowed to fall to 21 inches. The exposure period should be three hours.

Precautions. As ordinarily used, the danger to human beings and higher animal from breaking vapours of ethylene oxide is not great, it being less harmful than fumes of hydrochloric acid and sulphur dioxide, more harmful than chloroform and

carbon tetrachloride but all the same precautions have to be taken against breathing of the gas as in the case of any other dangerous gas. It does not possess enough odour to warn of high concentrations but causes intolerable irritation to the eyes and nose when present in high concentrations. Even in comparatively safe concentrations it causes although moderate, distinct irritation which must be taken as a warning to avoid serious injury. In the case of guinea pigs, exposure to the gas has resulted in irritation of the respiratory system sometimes resulting in pneumonia. In man, prolonged exposure causes a form of cyanosis which can be counteracted by administration of carbon dioxide gas. Grains fumigated with ethylene oxide do not lose their milling or baking qualities but their germinating power is destroyed. *It should not therefore be used for fumigating seeds intended for germination. The gas should also not be used for fumigating live plants.* As mixtures of ethylene oxide and carbon dioxide contain large percentage of the latter gas which when released in the air decreases percentage of oxygen below the safety limits resulting in suffocation and rapid breathing, the use of a gas mask and canister at fumigation doses is precluded, although these could be used to enter the structure during the aeration process. A respirator fitted with the appropriate filter should be worn by operators using 'Etox'. In England 'Degea' mask with initial 'A' and having a brown filter specially manufactured for use with 'Etox' is used. Ordinary rooms fumigated with the T- gas should be ventilated for at least 20 hours and trade premises for at least 12 hours after fumigation. If the fumigation period is 24 hours or less and a very exact determination of the gas residue is made before the use of the premises is permitted, a ventilation period of six hours may suffice. T-gas should not be used in the presence of naked lights owing to the risk of fire or explosion, the lower limit for the latter being a mixture of air with 3·6-3·7 per cent T-gas. When the T- gas is used for fumigating rooms, all heating devices should be removed prior to fumigation and ashes in fireplaces have to be drenched with water.

Fumigation chambers

As the fumigants can act best and without any risk only in tight enclosures, the construction of fumigation chambers requires considerable care. They are an important part of every plant quarantine station. Ordinarily all modern plant quarantine stations must be provided with vacuum fumigation chambers which can also be used for ordinary atmospheric fumigation. Separate chambers for atmospheric fumigation may also be used.

Whatever type of fumigation chamber is used, experience of nearly 25 years with fumigation of nursery stock, seeds, grain and other agricultural produce in other countries indicates that if a treatment is to be used to alleviate quarantine rejection and kill completely the insects in the commodity, all possible factors which influence its effectivencess must be under the control of the operator. The chamber has therefore to be (i) constructed in such a manner as to permit no leaks ; (ii) insulated to avoid temperature fluctuations ; (iii) equipped with proper accessories for measuring the fumigant ; (iv) equipped with heaters to permit temperature control ; (v) equipped with means of noting the inside temperature at all times from the outside and (vi) equipped with a humidifier for use when necessary.

Atmospheric fumigation chamber

The simplest type of fumigation chamber consists of a gas tight room and door. Inexpensive chambers can be made of sheet metal or plywood, their construction being altered to suit the conditions under which they are to be used. All such chambers should be also provided with an exhaust blower and shut-off valve to dispel the gas completely after fumigation. This is popularly called an atmospheric fumigation chamber because the fumigation is performed under ordinary atmospheric pressure. The size of the chamber varies to suit particular requirements. The floor may preferably be made up of good grade 1×8 tongue and groove, studding and rafters being 2×45 set 22 inches apart, sheathed inside with 1×8 tongue and groove, outside with a good plaster board material. The space between sheathing should be filled with ground cork for heat insulation only if chamber is exposed to low temperatures. The inside of the chamber is lined with a good roofing tin with soldered seams. Over the tin floor a latticed platform made in sections (so as to be easily removed for cleaning the floor) should be laid for protection and so that the load to be fumigated is raised off the floor, allowing the gas to get under it. The most important part of a chamber is a gas tight door. It should be about 4 ft.× 6 ft. in the case of large chambers and be provided with a sponge rubber gasket. For usual conditions in a chamber of 1,000 c. ft. capacity the utility blower No. 1½ with 7½ in. outlet and inlet placed preferably at the posterior end will suffice. The blower case will have to be made air tight by means of a gasket in the casing joint and packing around the fan shaft where it passes through the casing. The temperature of the material to be fumigated should be above 70°F., throughout the period of exposure to HCN or methyl bromide gas. In places where the temperature of the room and the material to be fumigated are below 70°F. a sheathed chamber with heating means is provided in a fumigation chamber and the material allowed to remain in the chamber prior to fumigation until it is above 70°F. Where the temperature of the material and the room containing the chamber as is usual in India above 70°F. no insulation, outside sheathing or a heating means will be required. However, when necessary as a source of heat, steam or hot water are satisfactory and for this purpose a pipe of sufficient radiation capacity must be run into and around the chamber as near to the floor as possible. Electric heaters of the exposed fire type should not be used, as this would change methyl bromide to hydrobromic acid which is injurious to commodities and equipment. A standard hot water radiator equipped with electric bayonet heaters and thermostatically controlled so as to maintain the chamber at the required temperature is the most suitable one. A brass marine port light with an opening of six inches should be installed on one side near the door about 5 ft. 6 in. above the floor and a thermometer located in the inside of the chamber in front of the port light so that temperature can readily be read from outside. A small electric fan with explosion proof motor should be located on a shelf preferably at the upper left hand corner of the chamber, near the door. This is to circulate the gas. Wiring switches, etc. for blower fan, and light and the control for heat should be located outside of the chamber. All wiring should be run from switch box into vault through one or more 'L' shaped conduits having their inside opening pointed upward. After the wiring, etc. has been permanently fitted

up, paraffin with a high melting point or any other similar material should be poured into the 'L' tube to seal it off thoroughly.

An improved atmospheric chamber with circulatory system of approximately 1,000 c.ft. capacity can also be constructed. After the gas has been introduced into the chamber, the blower is started and with the proper valves opened a continuous and thorough agitation of the gas mixture is affected throughout the chamber. The advantages of such systematic agitation are (i) that it ensures rapid penetration of the gas into the material to be fumigated, thereby killing the insects imbedded in it and shortening the period of exposurs considerably and (ii) that it greatly accelerates ventilation of the chambers and removal of the last traces of the gas, thereby making it possible to remove the fumigated material from the chamber in much shorter time.

Methods of loading and operation of chambers. The commodity to be fumigated should be stacked in criss-cross fashion in a number of rows with a few inches of space between the rows. A few inches of space between the walls of the chamber all round and the commodity should be left. An air space of three or four feet should also be left at the top of the chamber above the commodity. This arrangement allows the gas to circulate and penetrate properly.

After the material to be fumigated is loaded in the chamber and if the temperature in the chamber is below 70°F., heat is turned on till the temperature comes to this level. The port light is closed and the blast gates on blowers are closed by closing valve over blower. An inspection of these is very essential. The chamber door is closed and tightened by means of the clamps, then locked. The electric fan is next turned on at low speed. Both valves in ducts should be opened and valve in discharge line to atmosphere closed. Blower is then turned on and operated at half speed for two to four hours. When liquid HCN or methyl bromide is used in atmospheric fumigation the dosage is measured by placing the cylinder on a portable platform scale, located along side the chamber. The scale beam is set for the required dosage, the liquid HCN or methyl bromide discharged into the chamber and when the scale beam tips, the cylinder valve is closed. In the case of HCN after the required dosage has been discharged into the fumigation chambers it is necessary to blow out the gas remaining in the hose and piping and also to release the air pressure in the cylinder.

Opening chamber. When the exposure period is completed, exhaust valve is opened, and exhaust fan started. In the case of improved chamber circulation system, all ducts and discharge valve to atmosphere and the byepass valve should be opened and the fan started. The port light is opened to admit air to chamber. When the blower has run for about 15 minutes at full speed the chamber door is opened by about an inch and blower is kept running for about 15 to 20 minutes, then the chamber door is opened and the objects or material treated are removed. Electric fan is then turned off and lastly heat if used and the blower are turned off and all the valves are closed.

To avoid confusion in valve operation the discharge valve to chamber which is the master valve for discharge to chamber should be painted with a distinctive colour. It must be remembered that when the discharge valve to chamber is opened for circulation the other valves i.e., the discharge valve to atmosphere and the bye-pass valve should be closed while for the venting period, it is *vica versa.*

Vacuum fumigation chamber

A vacuum fumigation chamber is a gas tight steel chamber with a tight sealing door and is equipped with a vacuum pump to exhaust all the air from the material under fumigation. This is of special advantage where time is an important point for consideration. In atmospheric fumigation particularly when using HCN gas it has been found that penetration of the gas is slow and limited. This is specially so when tightly packed material or plant material with insects deeply imbedded in plant tissues have to be fumigated. Thirty inches of mercury on a gauge represents complete vacuum at sea level. In vacuum fumigation, the air from the fumigation chamber is pumped out until a vacuum of 28½ in. of mercury is indicated on the gauge. The exhaustion of air from the chamber will also remove the air from within the commodities in whatever type of container they are placed in. Vacuum chamber is provided with HCN volatilizer for introducing the required dosage of liquid HCN from a cylinder into the chamber. After the air has been exhausted, the HCN gas which is admitted immediately fills the space previously occupied by the air, thus forcing the fumigant through the material under fumigation.

The gas is allowed to remain in the chamber under vacuum for the period of time necessary to kill the insects in the commodity under fumigation. At the end of the fumigation period, the gas is withdrawn from the chamber by means of the vacuum pump. Air is then allowed to enter the chamber until normal atmospheric pressure is reached. The admixture of the remaining gas and air is again evacuated. Later fresh air is again allowed to enter the chamber. This procedure which is known as 'Air washing' removes any residual gas from the chamber. Vacuum fumigation chambers are equipped with exhaust fans to shorten the time of air washing. The use of this fan in operation, clears the chamber of residual gas in a very few minutes making it possible for workmen to start unloading the chamber immediately after the vacuum in the chamber is broken. The fan should be kept running during the entire period of unloading.

Vacuum fumigation chambers can be constructed to any size, according to individual requirements depending upon the maximum amount of commodity which has to be fumigated in a particular period of time at each loading. They may be installed singly or as dual units (Plate V, fig. 8) either rectangular or circular in shape with doors swung on Jib cranes or on hinges. They may have doors at both ends or only at one end. The present tendency in most countries is to have chambers with doors at both ends to expedite simultaneous loading and unloading of goods placed in truck trains. Also so that there is no wastage of space, rectangular chambers are preferred. Vacuum pumps of the chambers are ordinarily of the horizontal piston type guaranteed to evacuate to required vacuum in specified time. They may be driven by electric motor, gasolene or steam engine.

Vacuum fumigation ensures proper penetration of the gas and is the most suitable method for use when closely packed material, like bales of cotton, or hogs heads of tobacco are to be fumigated and the exposure required for vacuum fumigation is about one tenth the time required for atmospheric fumigation. During vacuum fumigation, the fumigated commodity absorbs large quantity of the fumigant. This brings the gas into direct contact with the insects and their eggs which may be deeply placed in the commodity, plant material or plant product. 'Post fumigation' effect while using HCN and methyl bromide gas in vacuum chambers is also considered by some to be an important feature because during the period the gas is being given off from the fumigated material it continues to function in killing any insects or destroying any eggs which may have escaped being killed during the process of fumigation in the chamber. All materials fumigated under vacuum should be allowed to aerate in normal storage for at least 74 hours after fumigation.

When a chamber is first put into operation, the aeration time should be checked at the completion of several fumigations. When methyl bromide is used, this checking is done through the use of a halide leak detector torch. After several such checks with the torch, a minimum aeration period should be set up for the chamber which allows for a reasonable safety period. When HCN is used for fumigation, its presence can be tested with the help of methyl orange test papers.

OTHER METHODS OF DISINFESTATION

Hot water treatment

This treatment can be used for narcissus bulbs infested with bulb flies and is given in large tanks about 3 to 4 feet high (Plate VI, fig. 9). The bulbs are placed in a rectangular wire bag and lowered into the tank with the hot water. A presoak treatment for two hours in the hot water at 75°F. is first given. The material is then kept between 110°F. for 4½ hours. The hot water has to be kept stirred up during treatment by means of special rollers at the bottom of the tanks. But it can be done even by means of a long stick.

Hot water treatment can also be used against sugarcane borers in imported sugarcane.

Soil sterilisation

Under the Federal regulations, soil from foreign countries is not permitted entry in the U. S. A. If by any chance plant material is intercepted with soil, the latter is removed completely and sterilised in an autoclave. The temperature has to be raised to 129°F. at 15 lb. pressure for half an hour. A similar procedure in India would be necessary to prevent soil bacteria, insects and nematodes entering this country.

Refrigeration

In the case of certain fruit pests like the Mediterranean fruit fly, it has been found that if the fruits are held at 31°F. for 11 days, all stages of the fly are killed

This method of disinfection is imposed as a quarantine requirement for fruit imported into the U. S. A. from the South America and the South Africa. The fruit is precooled at this temperature and then loaded in special refrigerator ships. This temperature, i.e., 31°F. is kept up during the voyage. Automatic temperature recorders which keep an exact record of temperature of the refrigerators are examined on arrival at the port of entry in the U. S. A. The other recommended refrigeration treatments against the Mediterranean fruit fly in fruit are 13 days at 33°F., 14 days at 34°F., 16 days at 36°F. and against *Bactrocera cucurbitae* for 15 days at 35°F.

Oil dip

Dipping of insect infested nursery stock and fruit in oil emulsion is prescribed in connection with some plant quarantine regulations. This method is only suitable for insect pests on the outside of the plant material or fruit and is adopted in California for imported citrus fruit and balled citrus stock.

In the case of fruit like Mexican limes and other approved sour limes complete submersion for a period of not less than 5 minutes in a 3 per cent concentration of an oil emulsion of the mayonnaise type (the stock emulsion of which shall contain not less than 80 per cent oil by volume of an oil that shall test not less than 65 viscosity seconds saybolt and not less than 90 unsulphonated residue) is carried out. Apparatus used for this treatment, is a large vat so constructed as to permit complete submersion of the fruit and is equipped with an agitator that will insure a dipping medium of uniform consistency throughout. The emulsion is heated and kept at a temperature between 50°F. and 100°F. during time of treatment. Dipping tank has to be completely drained and cleaned and new dip of fresh ingredients prepared if it becomes fouled with debris. In the case of hard water, softener has to be used.

In the case of balled citrus the pest concerned is citrus bud mite, *Eriophyes sheldoni*. The pre-treatment requirement for this is that the dipping vat must be of an approved type with proper facilities for agitation of solution and having a minimum capacity of 75 gallons. Treatment requirements are that the oil must be of an emulsive type with viscosity from 60 to 70 seconds saybolt and having an unsulphonated residue test of 90 or above. Use emulsion at rate of 10 qt. to make 75 gallons dipping solution. All parts of foliage, branches and trunk must be immersed and withdrawn twice.

After treatment the trees are kept in a vertical position in a location free from wind and direct sunlight for a period of 48 hours.

Superheating and team sterilization

High temperatures for disinfection of plant material, plant products, grain and seeds are used in certain cases in connection with quarantine work. These high temperatures may be applied directly in chambers or by steam sterilisation.

For example U. S. Federal regulations against the spread of pink bollworm requires certification for inter-state movement of cotton seed. These certificates

are issued only to approved gins in lightly infested area if the seed has been heated to a temperature of 150°F. for a minimum period of 30 seconds as a part of the continuous process of ginning under the supervision of a quarantine inspector and subsequently protected from contamination. In the case of inter-state movement of cotton seed originating in heavily infested areas, limited permits are issued for inter-state movement of cotton seed after the seed has been treated under supervision of a plant quarantine inspector and when it is consigned only to contiguous lightly infested areas for processing therein in an oil mill authorized by the Chief of the Bureau of Entomology and Quarantine under the following conditions. When the seed has been treated and protected as mentioned above and (*a*) when given a second heat treatment at a temperature of 155°F. for a minimum period of 60 seconds under the supervision of an inspector at a plant operated separate and apart from the gin or gins which applied the initial treatment as a part of the continuous process of ginning or (*b*) when the seed is given, under the supervision of a plant quarantine inspector the foregoing second heat treatment at the designated oil mill on arrival. The carriages or any other vehicles conveying the seed to the designated oil mills are also required to be cleaned and sterilized under the supervision of an inspector, immediately after unloading.

A number of cotton seed sterilizers have been developed in the U. S. A. Some of the important types are (i) Gas-heated revolving Drum Steriliser, (ii) Jacketed Conveyers Trough Steriliser, (iii) Brookfield Improved Steam Steriliser, (iv) Brookfield Gas-heated Type Steriliser, (v) Wellcasing Steam Jacketed Type, (vi) Three-Tier Type and (vii) Vertical Steriliser and Heater. Various kinds of superheaters for drying the steam have also been developed. The most important part of these sterilisers is the series of 10-feet sections of jacketed conveyer troughs, all connected so as to make one continuous trough of a length required for heating the cotton seed. Perforated steam pipes extending the entire length of these troughs are mounted inside the trough just above the path of the seed which is moved forward by a conveyer screw. The intake steam pipes are connected to the steam pipe from the boiler and so the live steam from the perforations gets directly ejected into the moving seed. A thermo-graph bulb is installed within a plain conveyer trough about the middle of its length to record the temperature of the seed. The ginners prefer a machine to give the seed a thorough drying and at the same time allow to run the conveyer screw at a reasonably rapid rate.

In the case of ears of corn one of the approved methods of disinfection against the European corn borer is their heating in a chamber at an air temperature of not less than 168°F. for a period of not less than two hours. The ears of corn have to be spread out not more than one layer deep on slat or wire shelves in the chamber and the time of sterilization shall begin when all thermometers reach 168°F. after corn has been placed in the chamber.

In the case of broom corn and articles made of broom corn, steam sterilization under vacuum is prescribed. Air pressure in the chamber is reduced to 25 in. vacuum at first. Then steam is introduced until positive pressure of 10 lb. is

obtained. This pressure has to be sustained until constant temperature in all parts of the chamber is attained.

Live steam sterilization of railway carriages is also an approved method for disinfecting carriages infested with cotton seed having pests. The carriages have to be made reasonably tight and the steam let into directly from the boiler until the seed is softened. Fumigation with HCN being more effective and certain, has replaced this method.

In the case of fruit and vegetables, vapour heat treatment is prescribed. Heating has to be for a period of not less than 14 hours during which time the temperature at the approximate centre of the fruit should be 110°F. and maintained at this temperature for eight hours of such treatment. This treatment is prescribed against the introduction of Mexican fruit fly. The steam has to be applied in such a manner as to secure uniform distribution of the heated air and so that it does not discharge directly on the fruits.

Introduction of steam into vacuum tanks used for fumigation and maintaining a temperature of 122°F. for three minutes has been found to kill several species of insects infesting cereal products including the resistant eggs of *Tribolium confusum*. Fumigation using methyl bromide has replaced this method completely.

Thermal vacuum process using a vacuum chamber can be used against pests of tobacco. In using this treatment the hogsheads are placed in the chamber and the air exhausted till a vacuum of 29·5 inches is registered. This vacuum is held for five minutes. Live steam at a temperature of approximately 300°F. and a pressure of 95 pounds is slowly admitted until the vacuum within the chamber is reduced to about 18·5 inches. The chamber is then again evacuated to a reading of approximately 27·2 in. and this vacuum is held for three minutes after which it is released. The chamber is then opened and the hogsheads are reRoved.

Used bags and returned products can be sterilized by placing them in a heating chamber or vault made of bricks or concrete designed to avoid loss of heat. A small unit heater can be employed; otherwise wall radiation of 20 sq. ft. per 100 cubic feet of vault-space would be sufficient to provide the required amount of heat. The vault should have a false or raised floor to permit circulation of hot air under the materials to be heated and built-in racks for separating bags of flour, etc. and to enable heat to penetrate milled cereals properly. When wall radiation is used, to prevent stratification of the heated air and for circulating it thoroughly, a fan designed for operation in high temperature must be provided inside the vault. Using a steam pressure of, from 50 to 75 pounds a temperature up to 200°F. can be quickly obtained and maintained. With these vaults at temperatures between 180° and 200°F., bags of flour, etc. can be completely freed from insect life in 24 hours.

DISINFESTATION AT AIRPORTS

Disinfection of airports

Rapid development of air transportation has brought us much closer to the insect pests of foreign countries. In spite of regulations preventing passengers in

planes bringing plant material, thousands of interceptions of insects are being made in cargo shipments, passengers' baggage and parcel post and as stowaways in various countries. Insect aliens coming as stowaways in airplanes are very dangerous and present a serious international problem. Some of these insects may even be vectors of plant diseases. The insect problem as applied to airplanes is therefore an international problem and India must take due recognition of it.

There must therefore be rigid control of insects, specially the economic pests— breeding on and near all places where aircraft may be parked. Cultivation of crops on or in the vicinity of airports should be prohibited as such cultivated areas can serve as centres of infection. Any miscellaneous vegetation forming a thick area of plant cover should also be removed and grass on airfields should be always kept closely mowed. All airports should also receive special regular insecticidal treatments by spraying with D. D. T. or other insecticidal solutions or suspensions. For this in the U. S. A. the liaison type of aircraft like L-5 is fitted up with aerial spraying appratus. This must be made available in all Indian air ports. Parked aircraft especially those in transit should be located as far as possible away from all areas of vegetation preferably on wide concrete aprons in front of hangers and operations building. Parked aircraft should be as much as possible kept closed up. Parked aircraft should never be left at night with the interior lights burning, specially if the doors and other openings are not tightly closed.

Disinsectization of foreign aircraft

The Quarantine Inspector must be at the side of the aircraft with spraying equipment as soon as the plane arrives and stops on the airfield. Immediately upon arrival, data concerning the time and method of disinsectization should be obtained from the flight personnel. If the plane has not been sprayed in flight in accordance with regulations, all openings must remain completely closed except to admit the inspector and the plane sprayed immediately with passengers and crew aboard. All baggage compartments accessible from outside the plane should also be sprayed immediately. Flight personnel should not be allowed to leave the plane until the disinsectization process is completed. If certain officials are given permission to board before the plane is released from quarantine, all such persons must remain within the plane until disinsectization is completed. The inspector must see that all windows and other openings are securely closed and that no spray is released until the plane is completely closed. He must work rapidly, opening interior compartments as he walks forward and great care must be exercised by him to insure a thorough and even distribution of aerosol spray throughout the aircraft. Interior compartment doors should be kept closed, each compartment being sprayed separately. Trap doors, cabinet and cupboard doors, tops of storage boxes should be opened so that the spray can penetrate into all potential insect hiding places. He must take care to conscientiously direct the spray into all semi-closed spaces such as under seats, behind the instruments, tanks and apparatus where insects may remain hidden. All spaces behind and between cargo and baggage are especially important and should have the spray deliberately directed into them. The proper amount of

insecticide to be dispensed has to be determined by knowing the cubic contents of the aircraft. When using the American military type of aerosol bomb, the dosage recommended on the bomb should be doubled. Ordinarily in such cases the spraying time must be 16 seconds per 1,000 cubic feet of aircraft space.

Spraying time

Spraying time for aircraft in general use should be as follows:

	Seconds
DC-3 (C-47) Cabin	32
Baggage compartment	4
DC-4 (C-54) Cabin	48
Baggage compartment	8
DC-6 Cabin	80
Baggage compartment	8
Constellation—Cabin	70
Baggage compartment	8 each

The above figures are *minimum desirable.* The Quarantine Inspector must use his judgement in determining whether the plane is adequately sprayed after this time has elapsed. The above figures should also be revised according to the type of aerosol used in India. In California 'aerosol bombs' produced by Bridgeport Brass Co., are used for spraying. Their formula is D. D. T. 3 per cent, pyrethrins 0·4 per cent, hydrocarbon oil 1·6 per cent, polymerised naphthalene 15 per cent and Freon 80 per cent. The U. S. D. A. Aerosol formula is Freon 85 per cent, D. D. T. 3 per cent, cyclohexanone 5 per cent, pyrethrum 5 per cent and lubricating oil 2 per cent, this aerosol being used at the rate of 20 gm. for 1,000 c.ft. In Hawaii, to the U. S. A. formula is added Technical Chlordane (Velsicol 1068 or Octa-Klor). This has greatly increased the insecticidal value of the aerosol in killing insects often difficult to be killed like the large heavy bodied Hemiptera and Coleoptera.

Aircraft quarantine declarations which must be handed over to the Indian Quarantine Officer by the Aircraft Commander must be examined by the Plant Quarantine Inspector to see if any plant material or insects are manifested to be aboard the aircraft.

Disinsectization of aircraft before leaving an airport in India

Plant Quarantine Inspectors must inspect all baggage and commissary stores of a plane before departure. No unauthorised plant material other than fruits for consumption enroute should be permitted in a plane leaving India. Ministry of Agriculture Airplane clearance certificate should be issued to the Chief of flight staff of the plane.

After loading of fuel, baggage, cargo, passenger and crew and immediately prior to the warm up of the engines all parts of the plane must be sprayed with aerosol. During the process of disinsectization the engines should not be operating. With all doors, windows, hatches and other openings to the exterior closed, thorough spraying should be done in all the cabins, cockpit, baggage, cargo and other compartments and enclosed spaces. If any of these portions are inaccessible from within the plane, they must be sprayed when loading is completed. The plane must be certified in the clearance of the aircraft, as well as signalled to the control tower. Aircraft should not be cleared for take off until the disinsectization has been indicated to the control tower. Operation officer must maintain appropriate records.

APPENDIX I

Extract from Notification No. 13-c, dated the 7 November 1917, Government of India, Department of Agriculture and Revenue

Directions for fumigation of plants

1. Remove the covers of the cases, wrappings of packages, etc. and spread the plants out in the trays together with all moss, wrappings, etc. in or with which they have been packed. taking care that the contents of each package are kept separate. The plants should be spread out loosely so that the gas will be able to penetrate between the plants.

2. Close up the plant chamber, wedging the door or lid securely.

3. Place the vessel containing the requisite quantity of water in the small external gas generating chamber. Add the acid to the water ; never pour the water into the acid or it will react violently and spatter about. Take the weighed quantity of cyanide, wrap it loosely in a piece of clean paper, drop it in the vessel of acid and water and immediately close and fasten the door of the generating chamber. Note the time.

Quantities of chemicals required :

For each fumigation Box (100 c.ft.)

Water	1 fluid oz.
Sulphuric acid	1 fluid oz.
Potassium cyanide (98 per cent)	½ oz.

For larger chambers. According to size, at the rate of :

Water	1 fluid oz.	per 100 c.ft. of internal capacity.
Sulphuric acid	1 fluid oz.	
Potassium cyanide (98 per cent)	½ oz.	

4. After three-quarters of an hour open the door or lid of the fumigated chamber or box taking care not to breathe any of the gas whilst doing so, and leave it open for at least a quarter of an hour before making any attempt to remove the plants. The trays may then be removed and the plants exposed to a current for air for another quarter of an hour after which they may be repacked.

NOTE.—In all cases when an agent of the consignee is in attendance, the unpacking and repacking of the plants will be done by such agent.

CAUTION

1. Living plants must not be watered immediately before fumigation, as wet foliage is liable to be injured by gas. If received wet, they should be allowed to dry before fumigation.

2. After fumigation, plants should be protected from the sun for several hours, preferably until the following morning. Do not, therefore, spread plants out in the sun's rays after fumigation to dissipate the gas.

3. Sulphuric acid is strongly corrosive and will burn into the skin. flesh, or clothing. If acid should accidentally be spilt on to the hands, plunge them immediately into a bucket full of water. If acid should be splashed on to the clothes, pour liquid ammonia on to the spot to neutralize the acid.

4. Potassium cyanide is a deadly poison if taken into the system, either if swallowed or introduced through any cut or wound in the skin. It is better, therefore, not to touch it with the bare hands but to wear gloves or to handle it with forceps.

5. Hydrocyanic acid gas, produced by the action of sulphuric acid on potassium cyanide is extremely poisonous if inhaled. It is colourless, non-inflammable and has a faint smell some thing like that of peachkernels or of some metals when these are struck together. Great care must be taken to avoid breathing in any of the gas before it has all escaped. Should symptoms of poisoning be noticed, the patient should be immediately removed and placed in the open air.

APPENDIX II

FIRST AID AND MEDICAL AID IN CASE OF ACCIDENTAL HCN POISONING*

In case of accidental HCN poisoning the unconscious man should not be rushed to the hospital as prompt action on the spot is essential. The patient must be carried to fresh air or to a room free from the gas and comfortably warm and made to lie down. First aid treatment should be immediately given and a doctor sent for at once. If the patient is conscious and breathing, an amyl nitrite pear should

*Adapted from Fumigation Manual by American Cyanamid Co.

be broken in a cloth and held lightly over the nose for 15 to 20 seconds. This should be repeated every 5 minutes for about 25 minutes if recovery is not seen. If the patient has stopped breathing, the patient should be given artificial respiration. If patient is unconscious but breathing, an amyl nitrite pearl should be broken in a cloth and held lightly over the nose for not more than 20 seconds repeating every five minutes for 25 minutes. The patient should also be given oxygen from an inhalator apparatus which all fumigatoria should be provided with. An unconscious person should not be given anything by the mouth. This is a very important point to be remembered. A person giving first aid should protect himself also with a gas mask if he has to get out a man from a space with HCN gas.

The first aid kit that must be available at all fumigatoria should consist of the following :

12 pearls of amyl nitrite

2 Ampoules of sodium nitrite

2 Ampoules of sodium thiosulphate

1 Sterile syringe 10 c.c.

1 Sterile syringe 50 c.c.

The kit must be ready for the doctor for use immediately he arrives on the scene. *The method of administering the antidote to be done only by the doctor* should be as follows. A trained assistant must be asked to break one at a time, pearls of amyl nitrite in a handkerchief and the latter held over the patient's nose for 15 to 30 seconds per minute. At the same time the doctor should quickly load his syringe one with a 3 per cent solution of sodium nitrite and the other with a 25 per cent solution of sodium thiosulphate. The administration of amyl nitrite should be stopped and 10 c.c. of the 3 per cent solution sodium nitrite should be injected intravenously at the rate of 2·5 to 5·0 c.c. per minute. Then with the same needle and vein or with a larger needle and new vein, 12·5 gm (50 c.c. of a 25 per cent solution) of sodium thiosulphate should be injected. The patient will subsequently have to be watched for 24 to 48 hours. If there is reappearance of signs of poisoning, injections of both sodium nitrite and sodium thiosulphate should be repeated but using each in one half of the dose used previously. The injections may be repeated for prophylactic purposes two hours after the first injections even if the patient is apparently well. If respiration has stopped but the pulse is beating, artificial respiration according to Schafer's manual method should be applied immediately to keep the heart beating. The handkerchief containing amyl nitrite should be laid over the patient's nose as it sometimes helps the respiratory movements to resume. As soon as signs of breathing appear, injection of the above mentioned solutions should be promptly made.

The prone pressure method of resuscitation (Schafer method) should be known to all fumigation operators and members of the staff of fumigation houses. If

necessary they should be given a special training. A full description of the method should also be prominently displayed in the fumigation houses. Oxygen—carbondioxide inhalation treatment is a valuable aid to drive the gas from the blood ; the apparatus for giving this treatment should therefore be close at hand always. It must however be borne in mind that the inhalator while being an aid to resuscitation cannot be a substitute for the Prone pressure method. The two may however be used simultaneously until the patient breathes without any assistance after which if necessary the inhalation only may be continued.

The Prone pressure method of resuscitation (Schafer system) is briefly as follows :

1. The patient should be laid on the stomach with head to the windward direction, one arm extended directly overhead, the other bent at the elbow. The face which is turned outwards should rest on the hand or forearm so that the nose and mouth are free for breathing.

2. The rescuer or person giving artificial respiration should kneel, straddling the patient's thighs, with his knees close to the hip bone.

3. The palms of the hands should be placed on the small of the back with the fingers resting on the ribs, the little finger just touching the lowest rib and with the thumb and fingers just out of sight.

4. The arms should be held straight and the body swung slowly forward so that its weight is gradually brought to bear on the patient. The shoulder should be directly over the heel of the hand at the end of the forward swing. The elbows should not be bent and the pressure should be maintained for approximately two seconds.

5. The body should be immediately swung back to remove the pressure completely.

6. The movements of compression and release should be repeated 12 to 15 times per minute.

7. This procedure should be carried on without interruption until breathing is restored, if necessary four hours or longer or until a doctor declares that life is extinct.

N. B.—In cases of gas asphyxiation, breathing has sometimes been reestablished even after eight hours of resuscitation. The doctor should therefore make a number of careful examination to determine absolute evidence for example, the onset of rigor mortis before the patient is declared dead and resuscitation is given up.

APPENDIX III

Important pests found in various foreign countries but not so far recorded in India

Name of insect	Family	Order	Host	Distribution	Remarks
Eriophyes quadrisetus F. Thomas (Juniper blister mite)	Eriophyidae	Acarina	*Juniperus communis* (Red cedar)	Europe	Easily introduced in nursery stock. Causes deformations in the fruit and needles
Eriophyes vitis Landois (Grape blister mite)	do.	do.	Grape (*Vitis* sp.)	Europe, Armenia. North America	Causes much damage to the vine. Imported into U. S. A. along with nursery stock
Paratetranychus citri Mc Gregor (Red spider mite)	Tetranychidae	do.	Citrus	U. S. A.	Does serious damage in arid coastal regions of California
Paratetranchus pilosus (Canastrini and Fanzago) (European red mite)	do.	do.	Most deciduous fruit trees; most injurious to plum, prune, apple and pear	Europe, U. S. A.	This pest which is widely distributed over continental Europe, was found in U. S. A. in 1911 and has rapidly spread. It is most injurious to apple, plum, prune and pear
Phyllocoptes oleivorus (Ashmead) (Citrus rust mite)	Eriophyidae	do.	Citrus	China, Japan, U.S.A., Phillipines, Straits Settlements	Reduces the value of half of the oranges and grape fruit in Florida
Rhizoglyphus (*Cocpophagus*) *echinopus* F. and R. (Potato root mite)	Tyroglyphidae	do.	Potato, parsnip, tulip, lilies	France, Italy Portugal, Palestine, Chile, Australia. California	Introduced into U. S. A. along with imported potatoes. Very destructive to roots and tubers
Tetranychus exsiccator (Zehntner) (Sugarcane red spider)	Tetranychidae	do.	Sugarcane	Java	Causes considerable damage by sucking juice from the plants which consequently wither away
Tetranychus sexmaculatus Riley (Red spider mite)	Tetranychidae	do.	Citrus	U. S. A.	Does serious damage in the Gulf States of U. S. A.

Adoxus obscurus Linnaeus		Coleoptera	*Epilobium angustifolium* (Fireweed and grape)	Algeria, France, Italy, Germany, U. S. A.	
Agrilus sinuatus (Olivier) (Sinuate pear borer)	Buprestidae	do.	Pear, hawthorn	Europe, U. S. A.	This is a European insect. Its first reocrd in U. S. A. was at New Jersey in 1894 where it appears to have been introduced
Agrilus occipitalis Eschsh. (Citrus bark borer)	do.	do.	Citrus	Philippines	A serious pest
Agrilus viridis Linnaeus (Flat headed wood borer)	do.	do.	Oak, beech, alder, aspen, linden, birch, rose, grape. maple. pine	Europe (Austria, Germany)	
Agriotes lineatus (L.)	Elateridae	do.	Tobacco, clover, hops, corn, potatoes, rutabagas	Practically all over Europe	Intercepted at quarantine in U. S. A. ports on potatoes and rutabagas
Agriotes pilosus Lacordaire (Tobacco wire worm)	do.	do.	Tobacco	Bessarabia, Portugal	
Anomola vitis Fabricius (Grape anomola)	Scarabaeidae	do.	Grape	Middle and Eastern Europe	
Anthonomus grandis Boheman (Cotton boll weevil)	Cureulionidae	do.	Cotton, *Hibiscus esculentus* and hollyhock	U. S. A., Mexico, Gautemala, Costa Rica, Cuba	This insect was first known only on wild cotton around Vera Cruz, Mexico. In 1880 it was found doing serious damage to cultivated cotton in the Moncolova District, Mexico. In 1892 it got introduced into U. S. A. It now causes 20 to 40 per cent loss of normal production. Loss estimated as $100,000,000 to $200,000,000 a year

APPENDIX III—*contd.*

Important pests found in various foreign countries but not so far recorded in India

Name of insect	Family	Order	Host	Distribution	Remarks
Anthonomus grandis thurberiae Pierce (Thurberia weevil)	Curculionidae	Coleoptera	Cotton, wild cotton species, *Thurberia thespesioides*	U. S. A.	Found in the State of Arizona in U. S. A. The adjoining States have a quarantine against the pest
Anthonomus rectirostris (L)	do.	do.	Cherry and other fruits	France. Denmark Austria, Bulgaria, Czechoslovakia	Often intercepted during quarantine work at ports. Larva of this insect feeds on seed preventing fruit from ripening
Aphanistichus consanguineus Ritsema Bos (The flat-headed leaf-miner beetle)	Buprestidae	do.	Sugarcane	Java	
Apogonia destructor Ritsema Bos (Javan sugarcane beetle)	Scarabaeidae	do.	Sugarcane, grasses and various plants	Java	
Athous niger Linnaeus (Tobacco wire worm)	Elateridae	do.	Tobacco, beet	Europe	
Baris laticollis (Marsh)	Curculionidae	do.	Turnip	England, France, Portugal, Czechoslovakia and Poland	Intercepted at quarantine in the U. S. ports
Baris lepidii Germar	do.	do.	Horse radish	England, France, Portugal, Czechoslovakia and Poland	do.
Brachyrhinus sulcatus Fabricius (Grape root weevil)	Brachyrhinidae	do.	Grape	Europe, America, Australia	Introduced into Australia and America from its original home in Europe
Brontispa froggatti Sharp (The leaf hispa)	Hispidae	do.	Cocoanut palm	New Britain and Solomon Islands	

Byturus unicolor Say (Rasberry fruit worm)	Dermestidae	Coleoptera	Raspberry and Loganberry	U. S. A.	
Cerambyx cerdo Linnaeus (Great oak borer)	Cerambycidae	do.	Oak, ash, walnut	Europe, Sudan, Tunis	
Ceutorhynchus pleurostigma (Marsh.)	Curculionidae	do.	Turnip	England, Denmark, Scotland, Holland, Poland, Germany, France	Intercepted during plant quarantine work at U.S.A. ports very frequently
Chaetocnema confinis Crotch (Sweet potato flea beetle)	Chrysomelidae	do.	Corn, sweet potato	U. S. A.	
Chaetochnema pulicaria Melsheimer (Corn flea beetle)	do.	do.	Corn	U. S. A.	
Chrysobothris femorata (Olivier) (Flat headed apple borer)	Buprestidae	do.	All fruit and shade trees	U. S. A., Canada	
Chrysobothris mali Horn (Pacific flat-headed borer)	do.	do.	do.	do.	
Colaspis brunnea (Fabricius) (Grape colaspis)	Chrysomelidae	do.	Corn, grapes, strawberries, beans, clover, buckwheat, potatoes, cowpeas, apples, muskmelons	North America	
Conotrachelus aguacatae Barber	Curculionidae	do.	Avocado seeds	Mexico, Honduras, Costa Rica, Gautemala, Equador, British Honduras	Intercepted several times during plant quarantine work at ports in U. S. A.
Conotrachelus crataegi Walsh (Quince curculio)	do.	do.	Quince	U. S. A.	
Conotrachelus nenuphar (Herbst) (Plum curculio)	do.	do.	Plum, pear, peach, apple, apricot, cherry, prune, cherry, nectarine, etc.	U. S. A. and Canada	On account of the very destructive nature, Japan is conducting a strict quarantine against this pest [Kuwana, 1926]

APPENDIX III—*contd.*

Important pests found in various foreign countries but not so far recorded in India

Name of insect	Family	Order	Host	Distribution	Remarks
Cotinis nitida (Linnaeus) (Green june beetle)	Scarabaeidae	Coleoptera	Various fruit trees and plants in vegetable gardens	U. S. A.	
Curculio cerasorum Herbst (cherry weevil)	Curculionidae	do.	Cherry	Germany	
Cylas brunneus Fabricius (Liberian sweet potato weevil)	do.	do.	Sweet potato	Liberia	
Cylas femoralis Faust	do.	do.	do.	do.	Intercepted at quarantine in U. S. A. ports
Diabrotica duodecimpunctata Olivier (Spotted cucumber beetle)	Chrysomelidae	do.	Various cucurbits, string and Lima beans, peas, potato, beet, asparagus, egg plant, tomato, cabbage, corn	U. S. A. Canada, Mexico	
Diabrotica longicornis (Say) (Northern corn root worm)	do.	do.	Corn	U. S. A.	
Diabrotica soror Le Conte (Western spotted cucumber beetle)	Chrysomelidae	do.	Various cucurbits	U. S. A.	
Diabrotica trivittata (Mannerheim) (Western striped beetle)	do.	do.	Cucumbers muskmelons, pumpkins, squashes, watermelons	U. S. A.	
Diabrotica vittata (*Fabricius*) (Striped cucumber beetle)	do.	do.	Cucumbers, muskmelons pumpkins, gourds, squashes, watermelons, beans, peas, corn	U. S. A. Canada, Mexico	

Diaprepes abbreviatus Linnaeus (West Indies sugercane borer)	Brachyrhinidae	Coleoptera	Sugarcane, orange, guava, avocado, mango, rose, Indian corn, sweet potatoes, Bahama grass, limes and other plants	Porto, Rico, Barbados, West Indies	
Diphucephala colaspidoides Gyllenhal (The cherry green beetle)	Scarabaeidae	do.	Cherry	Southern Australia	
Desiantha nociva Lea (Tomato weevil)	Curculionidae	do.	Tomato, potato, and other vegetable plants	Australia	
Disonycha xanthomelaena Dalman (Spinach flea beetle)	Chrysomelidae	do.	Spinach	U. S. A.	
Epicaerus cognatus Sharp	Curculionidae	do.	Potato	Mexico	Intercepted at quarantine in the U. S. A. potatoes from Mexico
Entochira lateralis Boheman Syn. *Holaniara picescens* Fairmaire (The Bibit kever)	Tenebrionidae	do.	Sugarcane, tobacco	Java	See remarks under *Holaniara*
Epilachna varivestis Mulsant (Mexican bean beetle)	Coccinellidae	do.	Beans	U. S. A., Canada	This is a very injurious species. Japan is conducting a strict quarantine against it [Kuwana, 1926]
Epitrix cucumeris Harris (Potato flea beetle)	Chrysomeliadae	do.	Potato	U. S. A.	
Epitrix fuscula Crotch (Egg plant flea beetle)	do.	do.	Egg plant	U. S. A.	

APPENDIX III—*contd.*

Important pests found in various foreign countries but not so far recorded in India

Name of insect	Family	Order	Host	Distribution	Remarks
Epitrix parvula (Fabricius) (Tobacco flea beetle)	Chrysomelidae	Coleoptera	Tobacco, potato, tomato, egg plant, chillies	U. S. A.	
Exosoma lusitanica (L.)	do.	do.	Cippolini, various bulbous plants and buds of grape	Morocco, Italy and France	Often intercepted on during quarantine inspection at U. S. A. ports
Euscepes batatae Waterhouse (West Indies sweet potato weevil)	Curculionidae	do.	Sweet potato	West Indies (Barbados, Antigua). Hawaii	This is often intercepted in quarantine work at California ports
Euscepes postfasciatus (Fairm.)	do.	do.		West Indies, Brazil and New Zealand	Intercepted at quarantine in U. S. A. ports
Fidia viticida Walsh (Grape root worm)	Chrysomelidae	do.	Grape and related wild plants	Eastern U. S. A.	Japan is conducting a strict quarantine against this insect [Kuwana, 1926]
Glyptocelis squamulata Crotch		do.	Grape	California (U. S. A.)	A very serious pest in some parts of California
Haltica ampelophaga Leesb. (Vine flea-beetle)	Chrysomelidae	do.	Grape, willow	France, Italy, Spain, Algiers	
Haltica quercetorum Fondr. (Oak flea beetle)	do.	do.	Oak, Hazel, willow, birch, tea rse beach, alder	Europe (Russia, Germany)	
Heilipus lauri Boheman	Curculionidae	do.	Avocado seed	Mexico, Honduras, Gautemala, Costa Rica, Equador and British Honduras	Intercepted a number of times at U. S. A. ports

Hispa wakkeri Zehntner (Sugarcane hispid miner)	Curculionidae	Coleoptera	Sugarcane	Java	
Holoniara picescens Fairmaire (Bibit kever)	do.	do.	do.	do.	A living example of this beetle was once intercepted in India in a parcel of sugarcane setts received from Java [Fletcher, 1921]
Hylurgopinus rufipes Eich (Elm bark beetle)	Scolytidae	do.	Elm, basswood, ash	U. S A Canada	
Hypera crinita Boheman (Potato leaf weevil)	Curculionidae	do.	Potato	Algeria, Tucis	
Hypera nigrirostris (Fabricius) (Clover bud weevil)	do.	do.	Red clover, alfalfa, sweet clover	Canada, U. S. A.	
Hypera punctata (Fabricius) (Clover leaf weevil)	do.	do.	Red clover, sweet clover, alfolfa	Southern Europe U. S. A., Canada	This insect is a native of S. Europe. It was not known in the U. S. A. until 1890, when it was first reported as injuring clover in New York. It has now spread all over U. S. A. and into Canada
Inesida leprosa Fabricius (Castilloa borer)	Cerambycidae	do.	Panama rubber (*Castilloa elastica*)	West and East Africa	
Lema cyanella Linnaeus (Grain leaf beetle)	Chrysomelidae	do.	Grasses, grains, especially oats	Serious in S. Europe	
Leptinotarsa decemlineata Say (Colorado beetle)	do.	do.	Potato, tomato, egg plant, tobacco, pepper, ground cherry, thorn apple, jimson weed henbane, horse nettle, belladona, petunia, cabbage, thistle, mullein	U. S. A., Canada, Spain, Austria, Switzerland, Italy, Belgium, France, Luxemburg, Germany, Lichtenstein	Original home of the insect in the U. S. A. is believed to have accompanied potatoes shipped to American Expeditionery Forces to Europe during World War I

APPENDIX III—*contd.*

Important pests found in various foreign countries but not so far recorded in India

Name of insect	Family	Order	Host	Distribution	Remarks
Leptops hopi Schouherr (Apple rot borer)	Curculionidae	Coleoptera	Apple, pear, cherry	Victoria (Australia)	
Macrodactylus subspinosus Fabricius (Rose chafer)	Scarabaeidae	do.	Grape	U. S. A., Canada	Japan is conducting a strict quarantine against this insect [Kuwana, 1926]
Melanauster chinensis Forst.	Cerambycidae	do.	Citrus, mulberry, apple, fig, casuarina	China, Japan, Korea	
Meligethes aeneus Fabricius	Nitidulidae	do.	Turnip, rape, cabbage and other crucifers	Europe	
Metamasius hemipterus Linnaeus (West Indies sugarcane borer)	Calandridae	do.	Sugarcane	West Indies, Trinidad	
Metamasius ritchiei Marshall	do.	do.	Pine apple	Jamaica, Mexico	Believed to have been introduced into Mexico from Jamaica
Metamasius sericeus Olivier (Sugarcane borer)	do.	do.	Sugarcane	Cuba, West Indies, Costa Rica, Barbados, the Canal Zone, Peru	Intercepted at U. S. A. ports a number of times during plant quarantine inspection
Naupactus leucoloma Boheman (White fringed beetle)	Curculionidae	do.	Peanuts, corn, sugarcane, cotton cowpeas, velvet beans, cabbages, sweet potatoes, lucerne	U. S. A., Australia	Has probably spread to Australia from the U.S.A.
Palacopus costicollis Marsh.	..	do.	Yams	Germany	Frequently intercepted at quarantine in the U. S. A. ports

Pantomorus godmani (Crotch) (Fuller's rose weevil)	..	Coleoptera	Citrus, avocado, walnut	California (U.S.A.)	
Pharaxonotha kirschi Reitt (Mexican grain beetle)	Cryptophagidae	do.	Corn, yams	Mexico, Guatemala, U. S. A., Brazil	Imported into U. S. A. from Mexico
Phyllotreta armoraciae (Koch) (Horse radish flea beetle)	Chrysomelidae	do.	Horse radish	U. S. A.	
Phyllotreta vittata Fabricius (Striped cabbage flea beetle)	do.	do.	Cabbage	do.	
Phytalus smithi Arrow (Brown hard back beetle)	Scarabaeidae	do.	Sugarcane	Mauritius, Barbados, Trinidad	Original home of the insect is Barbados. Introduced into Mauritius along with cane setts, it has been found to destroy entire fields
Phryneia spinator Fabr.	Cerambycidae	do.	Fig particularly. Also apple, apricot, peach, pear, plum	Africa	
Plocaederus ruficornis Newman (Mango bark borer)	do.	do.	Mango	Philippines	
Popillia japonica Newman (Japanese beetle)	Scarabaeidae	do.	Over 250 kinds of plants, deciduous fruit and shade trees, corn, soya beans, garden flowers, vegetables and various weeds	Japan, U. S. A.	This insect was imported into New Jersey (U. S.A.) from Japan on the roots of nursery stock about 1916
Premotrypes solani Pierce (Peruvian potato weevil)	Brachyrhynidae	do.	Potato	Peru and other parts of South America	Live specimens often obtained from South American potatoes in quarantine work at U.S.A. ports

APPENDIX III—*contd.*

Important pests found in various foreign countries but not so far recorded in India

Name of insect	Family	Order	Host	Distribution	Remarks
Promecotheca cumingii Baly (The cocoanut leaf miner beetle)	Hispidae	Coleoptera	Cocoanut	Philippines	
Pylloides attenuata Koch.	Chrysomelidae	do.	Hops, hemp	Europe (Russia, England)	
Rhabdocnemis obscurus Boisduval (Hawaiian sugarcane borer)	Calandridae	do.	Banana, sugarcane, cocoanut, sago-palm, royal palm, wine palm, papaya	Hawaii, Jamaica, Barbados, St. Kitts, Antigua, St. Lucia, British Guiana, Fiji, New Guinea, New Ireland, Tahiti, Queens land, Malaya archipelago	
Rhigopsidius tucumanus Heller (Argentine potato weevil)	Psaliduridae	do.	Potato	Argentine, Peru, Bolivia, Chile	Bores in potato making it unfit for use. Intercepted alive in U. S. A. from S. American potato
Rhizopertha collaris Erichson (Apple tree borer)	Bostrychidae	do.	Apple	Australia, Tasmania	
Rhynchophorus palmarum Linnaeus (Palm weevil)	Calandridae	do.	Palm, sugarcane	British Honduras, Trinidad, Lesser Antilles, Brazil	
Rhynchites cupreus Linnaeus	Rhynchitidae	do.	Plum, prune, cherry	Europe	
Saperda calcarata Say (Poplar borer)	Cerambycidae	do.	Poplar, cottonwood, aspen, willow	U. S. A., Canada	

Saperda candida Fabricius (Round headed apple borer)	Cerambycidae	Coleoptera	Apple, pear, quince	U. S. A., Canada	On account of the very destructive nature of this insect, Japan is conducting a very strict quarantine against it [Kuwana, 1926]
Scolytus multistriatus Marsham (European bark beetle)	Scolytidae	do.	Elms	do.	
Scolytus rugulosus Ratzeburg (Shot hole borer or fruit tree bark beetle)	do.	do.	Apple, peach, plum, cherry, quince	U. S. A., Europe	This insect is a native of Europe and is now generally distributed over U. S. A.
Sphenophorus sacchari	Curculionidae	do.	Sugarcane	Antigua, West Indies, Guiana	A parcel of sugarcane setts once received in India from Antigua was found to contain two living larvae and cocoons of this species. [Fletcher, 1921]
Sinoxylon perforans Schrk. (Grape-vine flat-headed borer)	Bostrychidae	do.	Grape, oak, elm, horsechestnut	Various countries of Europe	Bad on grape in Italy
Sinoxylon sexdentatum Olivier (Grape-vine flat-headed borer)	do.	do.	Grape, *quercus sessiflora*	Spain, France	
Stenoma catenifer Wlsm.	do.	do.	Avocado seed	Mexico, Costa Rica, Honduras, British Honduras, Equador, Guatemala	Often intercepted at U. S. A. ports during plant quarantine inspection
Tachypterellus consors Dietz.	Curculionidae	do.	Apple and other fruit trees	U. S. A.	
Tachypterellus consorscerasi List	do.	do.	do.	do.	

APPENDIX III—*contd.*

Important pests found in various foreign countries but not so far recorded in India

Name of insect	Family	Order	Host	Distribution	Remarks
Tachypterellus quadrigibbus magnus List (Western or larger apple curculio)	Curculionidae	Coleoptera	Apple, quince, pear, cherry, haw, etc.	U. S. A.	
Trichobaris trinotata (Say) (Potato stalk borer)	do.	do.	Potato, egg plant	do.	In some sections of U. S. A. this insect becomes so abundant as to destroy entire fields. Japan is conducting a strict quarantine against the pest
Uracanthus acutus Blackburn	Cerambycidae	do.	Peach, apricot, plum	Australia	
Xyleborus coffeae Wurth (Coffee beetle)	Scolytidae	do.	Coffee	Dutch East Africa Java, Tonkin	
Trypopremnon latithorax Pierce	Brachyrhinidae	do.	Potato	Peru	Often intercepted alive in S. American potatoes at the U. S. ports
Xyleborus perforans Wallaston (Sugarcane ambrosia beetle)	Scolytidae	do.	Sugarcane	British Guiana Dutch Guiana, Trinidad, and other parts of northern S. America	This pest can easily be transported in shipments of seed cane
Trypopremnon sanfordi Pierce	Brachyrinidae	do.	Potato	S. America	Frequently intercepted in S. American potatoes at U. S. ports during plant quarantine inspections

Stephanoderes hampei Ferrari	Brachyrinidae	Coleoptera	Coffee	Java, Ceylon, Malay Peninsula, Dutch East Indies, West Indies, Uganda, Belgian Congo, French West Africa, Kenya, Tanganyika, French Togoland, Cameroons	A very injurious pest. A large number of countries have a quarantine against this insect
Anastrepha ludens Loew (Mexican fruit fly)	Positae	Diptera	Guava, grape fruit, apple, citrus, mango, plum, pe ach, pear, quince, sapota, apricot, mammea	Mexico, Central America, Texas, Guatemala	Introduced into Texas, U. S. A. from Mexico Very destructive. Large sums of money have been spent for eradicating it. Several countries have quarantines against the pest
Anastrepha acidusa Walk (West Indian fruit fly)	do.	do.	Guava, grape, apple, citrus, mango, plum, peach, rose apple	Virgin Islds. St. Kitts and Nevis, St. Lucia, Cuba, Dominican republic, Jamaica, Haiti. British West Indies, Key West	Often obtained in quarantine work at U.S.A. ports
Anastrepha grandis (Macq.)	do.	do.	Pumpkins	Brazil, Argentina	do.
Anastrepha serpentina Weideman	do.	do.	Various kinds of fruits	....	
Anthomyia radicum Meigen (Radish fly)	Anthomyidae	do.	*Raphanus* spp. (including radish)	Europe	
Cecidomyia humuli Theobald (Hop midge)	Itonididae	do.	Hops	England	

APPENDIX III—*contd.*

Important pests found in various foreign countries but not so far recorded in India

Name of insect	Family	Order	Host	Distribution	Remarks
Ceratitis capitata Wiedeman (Mediterranean fruit fly)	Pos itae	Diptera	Citrus, peach, plum, apple, om e-granate, nectarines, pear, loquats, quinces, coffee berries, grape fruits, etc.	Tropical and sub-tropical regions, Bermuda, Brazil, Hawaii, Eritria, S. Africa, Spain, Portugal, Australia, Palestine, Egypt, Argentine, British East Africa, Algeria, Tunisia, Uganda, Dahomey, Nigeria, Congo, Rhodesia, Morocco, Tasmania, France, Albania, Greece, Italy, Sicily, Cyprus, Malta, Madevia, Canary Island, Madagascar, Cape verde	Doubtful record in India; believed to be from imported fruit. Not recorded again. Extremely destructive. U. S. A. has a stric-quarantine against it. Introduced into Florida. It cost $7,000,000 to eradicate
Chaetoda·us tryoni Froggatt (Queensland fruit fly)	do.	do.	C trus, apple, banana, apricot, custard apple, cherry, date, fig, grape, mango, plum. papaya, tomato, walnut	Queensland (Australia)	
Chortophila cilicrura Rondani (Shallot fly)	Anthomyidae	do.	*Allium* sp. (including shallot), asparagus	Europe	
Clinodiplosis mosellana Gehin (Grain gall midge)	Itonididae	do.	Wheat, rye, barley	do.	

Contarinia pisi Winn (Pea midge)	Itonididate	Diptera	Pea	Europe	
Dasyneura pyri Bouche (Pear leaf curling midge)	Itonididae	Diptera	Pear	Europe	
Dacus raratongae Froggatt	Trypetidae	do	Mango	Raratonga and Cook Islands	
Dacus tongensis Froggatt .	do.	do.	do.	Tonga	
Dacus vertabratus Bezzi .	Positae	do.	Several fruits .	Africa, Egypt, Italy, Greece, Portugal, Spain, Sicily	
Epochra canadensis Loew. (The currant and Gooseberry fly)	do.	do.	Gooseberry and currant	North America	
Eumerus strigatus Fabricius (Lesser bulb fly)	Syrphidae	Diptera	Onions, iris	Europe, U.S.A. .	Introduced into U. S. A. from Europe. Introduction reported first by Felt from Iris roots at Saratoga springs, N. Y. (U. S. A.)
Hylemyia antiqua Meigen (Onion maggot)	Anthomyidae	do.	Onion	Europe, U. S. A. .	Introduced into U. S. A. from Europe
Hylemia coarctata Fallen (Wheat bulb fly)	do.	do.	Rye, wheat, barley	Middle and north of Europe	One specimen recorded Colorado, U. S. A.
Lonchaea splendida (Metallic tomato fly)	Trypetidae	do.	Tomato, potato, egg plant and other Solanaceae	New Zealand, Australia, Pacific Islands	
Merodon equestris Fabricius (Narcissus fly)	Syrphidae	do.	Onion, narcissus and daffodil bulbs	Europe, the U. S. A., Canada and New Zealand	This insect is of European origin. Introduced into U. S. A., Canada and New Zealand. It is often encountered in quarantine work in foreign shipments of bulbs in U. S. A. ports

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APPENDIX III—*contd.*

Important pests found in various foreign countries but not so far recorded in India

Name of insect	Family	Order	Host	Distribution	Remarks
Oscinis frit Linnaeus (Frit flies)	Oscinidae	Diptera	Oats, barley, wheat, rye	Europe, America	Introduced into America from Europe
Phytomyza affinis Fallen (Marguerite fly)	Agromyzidae	do.	Tobacco, cosmos, celery, carrot, pea, helianthus, lettuce, dahlia etc.	Tasmania, New Zealand Australia, Europe, U. S. A.	Introduced into U. S. A.
Contarinia tritici Kirby (Grain gall midge)	Cecidomyiidae	do.	Wheat, barley, rye	Europe, U. S. A.	Introduced into U. S. A. Causes serious injury (Pierre)
Phytophaga destructor Say (Hessian fly)	do.	do.	Wheat, barley, rye	North America, Caucasus region of Russia	Introduced into U. S. A. It is believed to have been introduced in U. S. A. in straw bedding used by the Hessian troops during revolutionary war, as it was first noticed on Long Island in 1779. U. S. A. spends at least $100,000,000 a year against it.
Rhagoletis cingulata Loew (Cherry fruit fly)	Positae	do.	Cherry, pear, plum	U. S. A. and Canada	On account of the very destructive nature of this insect Japan is conducting a very stricted quarantine against it
Rhagoletis pomonella Walsh (Apple fruit or blue berry maggot fly)	do.	do.	Apple, blue berry, cherry	U. S. A. and Canada	A serious pest in U. S. A.
Trichocera hiemalis	Mycelophilidae	do.	Turnip, cabbage	England	

Trypeta musae Froggatt (Spotted fruit fly)	Positae	Diptera	Plum pear and other fruits		
Aleurodicus destructor MacKie (Cocoanut white fly)	Aleyrodidae	Hemiptera	Cocoanut palms	Philippines	
Aleurothrixus howardi (Quaintance)	do.	do.	Citrus	Florida (U. S. A.), West Indies, Cuba	
Aleurolobus olivinus Silvestri (Olive white fly)	do.	do.	Olive	Italy	
Anasa tristis De Geer (Squash bug)	Coreidae	do.	Cucurbits	U. S. A., Central America, Canada	
Blissus leucopterus (Say) (Chinch bug)	Lygaeidae	do.	Corn, wheat	U. S. A., Canada, Central America, Mexico	Very destructive; Japan is conducting a very strict quarantine against this insect. [Kuwana, 1926]
Chionaspis furfura Fitch (Scurfy scale)	Coccidae	do.	Apple, pear gooseberry, currant other deciduous and bush fruit trees	U. S. A.	Japan is conducting a strict quarantine against the scurfy scale
Biprorulus bibax Bred	..	do.	Citrus	Australia	A serious pest
Eurythroneura comes (Say) (Grape leaf hopper)	Cicadelidae	do.	Grape, Virginia creeper, apple	U. S. A.	The most important pest of the grape
Hetrocordylus malinus Reuter (Apple red bug)	Miridae	do.	Apple, pear	U. S. A., South eastern Canada	
Lepidosaphes ficus (Signoret) (Mediterranean fig scale)	Coccidae	Hemiptera	Fig	Algeria, U. S. A.	Introduced into California in 1905 on fig cuttings from Algeria

APPENDIX III—*contd.*

Important pests found in various foreign countries but not so far recorded in India

Name of insect	Family	Order	Host	Distribution	Remarks
Murgantia histrionica (Hahn) (Harlequin bug)	Pentatomidae	Hemiptera	All Cruciferae, potato, egg plant, okra, bean, beet, fruit trees and various field crops	Mexico, U. S. A.	
Perkinsiella saccharicida Kirkaldy (Sugarcane leaf hopper)	Cicadellidae	do.	Sugarcane	Hawaii, Australia	
Phoenicococcus marlatti Cockerell	Coccidae	do.	*Phoenix dactylifera*, *P. canariensis*, *P. reclinata*	U. S. A., Egypt Algeria, Mediterranean coastal plain and the Sahara oases	Egypt is believed to be the native home of this insect
Phylloxera vitifoliae Fitch (Grape phylloxera)	Phylloxeridae	do.	Grape	North America, France, Australia, S. Africa	This pest was introduced into France from America about 1860. Within 25 years this insect had destroyed nearly one-third of the vine yards more than 2,500,000 acres
Pseudococcus capensis Brain (Cape Mealy bug)	Coccidae	do.	Grape, pumpkin, red clover and a host of other plants	South Africa	One of the worst pests of grape in the S. Africa
Psylla mali Schmid Apple psylla)	Psyllidae	do.	Apple	Europe	
Psylla pruni Scopoli Plum Psylla)	Psyllidae	do.	Plum	Europe, Siberia	

Psylla pyrisuga Förster (The large pear psylla)	Psyllidae	Hemiplera	Pear	Europe, Japan	Very injurious in Central Europe and Japan
Pulvinaria aurantii (Cockerell) (Orange pulvinaria)	Coccidae	do.	Citrus	Japan	Clausen lists this species as third most important on citrus
Scotinophora lurida	Pentatomidae	do.	Rice, sugarcane	Formosa, Japan	Is very destructive in certain localities of Japan
Phoeococoris sulciventris Stal (Bronze orange bug)	..	do.	Citrus	Australia	
Stenocranus saccharivora Westwood (West Indies cane fly)	..	Fulgoridae	Sugarcane	West Indies	
Stephanites pyri Fabricius (The pear tingis)	Tingitidae	do.	Pear, apple, persimmon	Europe	A serious pest of apple and pear in Furope. Intercepted a number of times in persimmon fruit arriving in baggage from Italy at U. S.A. ports
Tomaspis varia Fabricius (Sugarcane frog hopper)	Cercopidae	Hemiptera	Sugarcane, corn, grasses	Trinidad	A very serious pest
Unaspis citri (Comstock) (White scale of orange)	Coccidae	do.	*Citrus* sp.	Recorded in several parts of the world	Introduced into some parts of U. S. A. along with nursery stock probably from the orient
Unaspis yanonensis (Kuwana)	do.	do.	do.	Japan, China	Very destructive. Frequently intercepted at quarantine in U. S. A. ports. The native home of this insect is believed to be China

APPENDIX III—*contd.*

Important pests found in various foreign countries but not so far recorded in India

Name of insect	Family	Order	Host	Distribution	Remarks
Cephus cinctus Norton (Wheat stem saw fly)	Cephidae	Hymenoptera	Rye, wheat, barley	North America	Very destructive in the U. S. A.
Cephus pygmaeus Linnaeus (European wheat saw fly)	do.	do.	Wheat, rye, timothy and other cereals and grasses	Europe, U. S. A.	This insect can be easily imported in straw. Introduced into U. S. A. found in New York and Pennsylvania States
Harmolita grandis (Riley) (Wheat straw worm)	Chalcididae	do.	Wheat	U. S. A.	Very destructive. Japan has a strict quarantine against the pest [Kuwana, 1926]
Harmolita tritici (Fitch) (Wheat joint worm)	do.	do.	do.	U. S. A.	do.
Janus compressus Fabricius (Bud stinger)	Tenthredinidae	do.	Pear	Europe	
Pamphilius flavirentris Retz.	do.	do.	Pear, plum, cherry	Europe	
Pteronidia ribesii (Scopoli) (Imported currant worm)	do.	do.	Currant, gooseberry	Europe, Canada U. S. A.	Imported into America from Europe about 1857
Termes australis Hagen (Victorian white ant)	Termitidae	Isoptera	Apple	Australia	
Alsophila pometaria (Harris) (Fall canker worm)	Geomatridae	Lepidoptera	Apple	U. S. A. and Canada	Japan is conducting a strict quarantine against this pest [Kuwana, 1926]
Anarsia lineatella Zeller (Peach twig borer)	Gelechiidae	do.	Peach, plum, apricot and almond	U. S. A.	

Antographa brassicae Riley (Cabbage looper)	Noctuidae	Lepidoptera	All plants of the cabbage family, potato and tomato	U. S. A., Canada and Mexico	
Argyroplace leucotreta Meyrick (False codling moth)	do.	do.	Plum, citrus, guava pomegranate, peach persimmo, olive, walnut	South Africa	
Argyresthia conjugella Zeller (Apple moth)	Hyponomeutidae	do.	Apple, cherry and plum	Europe, U. S. A., British Columbia, and Japan	Introduced into U. S. A along with nursery stock
Argyresthia vitidella Fabricius (Cherry fruit moth)	do.	do.	Cherry, hawthorn	England	
Argyrotaenia citrana (Fern) (Orange tortrix)	do.	do.	Citrus	California (U. S. A.)	
Blastodacna vinolentella H. S. (Pith moth)	Elachistidae	do.	Apple	England and Europe	
Boarmia gemmaria Brahm	Geometridae	do.	Grapes, rose, wild honey suckle	Europe	
Critripestis sagittiferella Moore		do.	Citrus	Malaya, Dutch East Indies	There is sometimes 100 per cent loss of grape fruit due to this
Clysia ambiguella Hübner (The Cochylis)	Tortricidae	do.	Grape	Europe	
Cnethocampa processiona Linnaeus (Oak procession moth)	Cnethocampidae	do.	Oak	do.	
Caleophora lutipenella Zell. (Oak bud moth)	Elachistidae	do.	Oak, birch	Germany	
Conogethes punctiferalis Guerin	Pyralidae	do.	Peach	Australia	

APPENDIX III—*contd.*

Important pests found in various foreign countries but not so far recorded in India

Name of insect	Family	Order	Host	Distribution	Remarks
Conopia exitiosa (*Say*) (Peach borer)	Aegeriidae	Lepioptera	Peach, wild and cultivated cherry, plum, prune, nectarine, appricot and ornamental shrubs of the genus prunus	U. S. A. and Canada	On account of its very destructive nature, Japan is conducting a very strict quarantine against it [Kuwana, 1926]
Cryptophaga unipunctata Donovan	Xyloryctidae	do.	Cherry, peach, honey suckle	Australia	
Cydia saltitans (Westwood) (Mexican jumping bean moth)		do.	Mexican Jumping beans	Mexico and U. S. A.	Encountered a number of times in quarantine work in Hawaii
Diatrea canella Hampson	Pyralidae	do.	Sugarcane and grasses	Trinidad, Grenada, Guiana	
Diatraea crambidoides Grote (Southern corn stalk borer)	do.	do.	Corn, sorghum, Johnson grass	U. S. A., Mexico South America	One of the most destructive corn insects in the South U. S. A. Often responsible for reduction in yields of 15 to 50 per cent
Diatraea lineolata Walker	do	do.	Sugarcane, grasses	Trinidad, West, Indies, Central and South America	
Diatraea saccharalis Fabricius	do	do.	do.	Mexico, West Indies, United States	
Diatraea striatalis Snellenhoeven	do	do.	do.	West Indies, Formosa and Java	

Ephestia elutella (Hübner) Tobacco moth	Pyralidae	Lepioptera	Cured tobacco, nuts, chocolate, and many other dried vegetable products	Practically cosmopolitan	Very bad in the U. S. A., on tobacco. Not recorded so far in India
Ereunetis flavistriata Walsingham (Sugarcane bud moth)	Tineidae	do.	Sugarcane, palms, banana and pineapple	Hawaii	
Epinota opposita Heinrich	..	do.	Beans, chillies, alfalfa, cowpeas	Peru and Mexico	Intercepted at quarantine in the U. S. ports
Hepialus humuli Linnaeus (Hop root borer)	Hepialidae	do.	Hops, potato, rape, corn, sorrel, dandelion	Europe	
Hyphantria cunea (Drury) (Fall web worm)	Arctiidae	do.	Apple	U. S. A. and Canada	Japan is conducting a strict quarantine against the pest [Kuwana, 1926]
Laspeyresia dorsana Fabricius (Pea moth)	Tortricidae	do.	Peas	Europe	
Ephestia kuehniella Zeller (Mediterranean flour moth)	Pyralidae	do.	Mostly found in flour, it will also attack whole grain of wheat bran, breakfast foods, corn and other grains and pollen in beehives	Europe, U. S. A., Canada and several other parts of the world	This insect is of European origin. Not recorded so far in India. Recorded in Canada for the first time in 1889, it has spread throughout Canada and U. S. A.
Laspeyresta nigricana Stephens	Tortricidae	Lepidoptera	Peas	Europe, Canada and U. S. A.	This insect is of European origin and has been in America since about 1900
Laspeyresia molesta (Busck) (Oriental fruit moth)	do.	do.	Apple, pear, peach, quince, plum	U. S. A., Canada, Japan, Korea, China, France, Italy, Australia	This insect is an oriental species not so far recorded in India. It was introduced into U. S. A., along with imported nursery stock

APPENDIX III—*contd.*

Important pests found in various foreign countries but not so far recorded in India

Name of insect	Family	Order	Host	Distribution	Remarks
Ochsenheimeria taurella Schiffermüller (Rye stem borer)	Tineidae	Lepidoptera	Rye, grasses	Europe	Very injurious to winter rye; may attack other grain crops
Omiodes accepta Butler (Hawaiian sugarcane leaf roller)	Pyralidae	do.	Sugarcane and grasses, sedges	Hawaii and Peru	Does serious damage sometimes. Is liable to importation in seed cane
Paleacrita vernata Peck (Spring canker worm)	Geometridae	do.	Shaded fruit trees, apple	U. S. A. and Canada	Japan is conducting a strict quarantine against this pest [Kuwana, 1926]
Papilio cresphontes Cramer	..	do.	Citrus	U. S. A.	A serious pest in Florida
Porthetria dispar (Linnaeus) (Gypsy moth)	Lymantriidae	do.	Conifers and other decoration plants	Europe, United States and Canada	A native of Europe. This insect was brought into U. S. A. in 1869. It has cost the Massachussetts State more than a million dollar a year for the last 20 years
Polychrosis botrana (Schiffermüller) (The pyralid of the vine)	Olethreutidae	do.	Grape	Germany, Austria, Hungary, Switzerland, France, Italy, Asia Minor	Very injurious. This insect has been often obtained in quarantine work at U. S. A. ports. Imported grapes have been found infested with larvae of the species
Laspeyresia schistaceana Snellenhoeven (Gray borer of sugarcane)	Tortricidae	do.	Sugarcane	Java	A very bad pest. Is liable to importation in seed cane
Leucinodes elegentalis Geunee	Pyralidae	do.	Tomatoes	Mexico, Brazil	Intercepted at the quarantine in U. S. ports

Leucoptera coffeella Stainton (Coffee leaf miner)	Lyonetiidae	Lepidoptera	Coffee	Parto Rico, Brazil Cuba	A serious enemy reported as causing 20 to 30 per cent loss
Lemuana iridescens Bethune-Barer (Coconut leaf moth)	Zygaenidae	do.	Coconut palm, royal palm (*Oreodoxa regia*)	Fiji	Very injurious to foliage
Liparia (*Lymantria*) *monacha* Linnaeus (Nun moth)	Lymantriidae	do.	Deciduous ornamental and forest trees	Europe and U. S. A.	This is a European species. Specimens were first collected in U. S. A. at Brooklyn N. Y. in 1902
Melittia satyriniformis Hübner (Squash borer)	Aegeriidae	do.	Cucurbits	U S. A Canada and South America	A very pernicious borer
Nygmia phaeorrhoea (Donovan) (Brown tail moth)	Lymantriidae	do.	Deciduous shade and fruit trees	Europe, Nova Sootia, New Brunswick and U. S. A.	A native of Europe. This insect was introduced in E. Massachusetts (U. S. A.) on imported nursery stock about 1897. Japan is conducting a strict quarantine against it [Kuwana, 1926]
Polychrosis viteana (Clemens)	Olethreutidae	do.	Grapes	U. S. A. and Canada	
Prays oleellus Fabricius (Olive moth)	Hyponomeutidae	do.	Olives	France, Italy, Spain	A very serious pest
Protoparce quinquemaculata Haworth. (Tobacco horn worm)	Sphingidae	do.	Tobacco, tomato, brinjal, potato, chillies	U. S. A.	
Protoparce sexta (Johanssen) (Tobacco horn moth)	do.	do.	Tobacco, tomato, potato, chillies and brinjal	U. S. A.	

APPENDIX III—*contd.*

Important pests found in various foreign countries but not so far recorded in India

Name of insect	Family	Order	Host	Distribution	Remarks
Pyrausta nubilalis Hübner (European corn borer)	Pyralidae	Lepidoptera	Millet, corn, potatoes, beans, beats	Europe, Canada, U. S. A., Guam, Japan, China	One of the most destructive pests of corn. Believed to have been introduced into N. America about 1908 or 1909 in shipments of broom corn from Italy or Hungary
Sesamia cretica Led. (Durra stem borer)	Noctuidae	do.	Sugarcane, corn, durra	Khartoum, Sudan	A very serious pest in Khartoum. Is liable to importation in seed cane
Sciopteron regale But. Grapegum worm	Sesiidae	do.	Grape	Japan	
Synanthedon tipuliformis (Linne) (Currant borer)	Aegeriidae	do.	Gooseberry, currant	North America	
Synanthedon tictipes (Grote and Robinson) (Lesser peach borer)	Aegeriidae	do.	Peach, plum, cherry, wild plum, wild cherry	U. S. A.	
Tinea granella Linnaeus (The wheat moth)	Tineidae	do.	Wheat, barley	Victoria, Australia, Europe, North America	Introduced into U. S. A. Causes serious injury to the seed heads
Tortrix ashworthani Newman (Light brown apple moth)	Tortricidae	do.	Apple	Australia	
Zeuzera pyrina Linnaeus (Horse chestnut borer)	Cossidae	do.	Elm, alder, ash, beach, birch, horse chestnut, linden, maple, oak, willow, poplar, buck thorn, spindle trees, mountain ash	Europe, North Africa	

Epacromia tamulus Fabricius	Acridiidae	Orthoptera	Sugarcane	Java	
Oxya intricata Stal	do.	do.	do.	Formosa, Java	
Scirtothrips citri (Moulton)	Thripidae	Thysanoptera	Citrus	California	Causes very great injury in drier regions of California and may do similar damage if introduced into India
Taeniothrips inconsequens Uzel (Pear thrips)	do.	do.	Apple, pear, appricot, cherry, grape, peach, and various other deciduous fruit trees	U. S. A. and Canada	On account of its very destructive habits, Japan is conducting a very strict quarantine against this pest

THE STRUCTURE OF XYLEM VESSELS IN THE NODAL REGION OF SUGARCANE IN RELATION TO ITS RESISTANCE TO RED-ROT (*COLLETOTRICHUM FALCATUM*, WENT)

By S. C. Varma, Ph.D., Cane Physiologist, and S. P. Mital, M.Sc., Senior Botanical Assistant, Main Sugarcane Research Station, Shahjahanpur

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(With two test-figures)

Recent investigations in the red-rot resistance of cane at Louisiana have indicated a close relationship between the structure of fibro-vascular bundles and disease incidence in cane varieties. It has been considered that the rapid spread of red-rot disease from one part of cane to another is partly due to the migration of spores through the vascular bundles. Efforts at this station were made to elucidate the structure of vascular bundles at the nodes of certain sugarcane varieties in order to establish a relationship, if any, between their nodal anatomy and the resistance they offer to the spread of infection from one internode to another.

Markedly resistant and likewise susceptible varieties of sugarcane were selected ; Co.453, Co.393 and *desi dhor* representing the former group and Co.312 and Co.213 the latter. *Saccharum spontaneum* which is known for its very high resistance to the disease according to Butler and Khan [1913] was also included. Soon after the plants were received from the field, their top portions consisting of a few internodes with foliage were cut under water so that transpiration current was not broken. The cut ends of these tops were then immersed in a fairly concentrated Indian ink suspension in distilled water where they were allowed to remain for 48 hours. After taking them out of the suspension only the last two internodes, with one node in between, were retained and all subsequent observations were confined to the internode just above the one cut. From this, transverse sections were cut within half an inch of the node and were examined under the dissecting microscope.

Total number of vascular bundles, as also those showing the ascent of ink were counted per unit area to find out the percentage of the latter. Ten counts were taken in each section, five being from the periphery touching the epidermis and the rest from the central region. Eight different clumps of each variety were tested separately. The percentages of ink-showing vascular bundles of the different varieties under study are presented along with the averages of their linear-infections of the last five years obtained from the Mycology Section of this Station in Table I.

In Co.393 and *Saccharum spontaneum* the nodal regions below the internodes studied were macerated with boiling caustic potash solution. The parenchyma was dissolved leaving a tangled mass of vascular strands which were separated and stretched on slides with a view to trace the path of ink-particles through term.

In another set of experiments tops of Co.213 and Co.393 were cut under water and placed in suspension of red-rot spores in distilled water with a little cotton-blue. In this case also cross sections of internodes were studied exactly in the same way as before, to find out if spores could travel through the vessels across the nodes.

TABLE I

Average percentages of ink-showing vascular bundles in the plants studied and their relative linear-infections

Varieties	Ink-showing vascular bundles per cent of total bundles	Linear-infections in cm. (average of 5 years)	Remarks
S. spontaneum	*nil*	Highly resistant	Canes having linear infections less than 30 cm. are considered to be resistant.
Co.453	2·7	22·5	
Desi dhor	2·7	11·7	
Co.393	6·7	18·7	
Co.312	20·9	94·3	
Co.213	22·8	116·6	

It will be observed from the Table I that there is a close parallelism between percentages of ink-showing vascular bundles and the linear-infections. It is seen that in Co.453, *desi dhor* and Co.393 there are very few vascular bundles showing the presence of ink and, also that lesion-lengths do not go beyond 22·5 cm. Co.312 and Co.213 with their lesion-lengths of 94·3 cm. and 116·6 cm. respectively, also have, in turn, by far the maxima for the ink-conducting vascular bundles, viz., 20·9 per cent and 22·8 per cent. It is also very significant to note that in *Saccharum spontaneum* ink particles have not crossed the node even through a single vascular bundle. Thus the marked concurrence observed between the figures for ink-showing vascular bundles and varietal linear-infections possibly opens an avenue for such vascular counts and mycologist's findings to go hand in hand.

Now from Table I it can be deduced that while ink particles can travel across the nodes through a large number of vascular bundles in susceptible varieties, frequency of such bundles is much less in resistant ones. Its possible explanation seems to lie in the characteristics of vascular strands of the resistant cane varieties. It will be seen in Fig. 1 that in one metaxylem ink particle stops abruptly at one place. This can be attributed to the metaxylem being made up of a series of elongated cells placed end to end to form a sort of pipe-line as expressed by Eames and MacDaniels [1925]. The ends of these cells can easily be marked out by constrictions found along the length of the ink-column in the vessel. These constrictions indicate the location of septa which usually dissolve away except, perhaps, at the

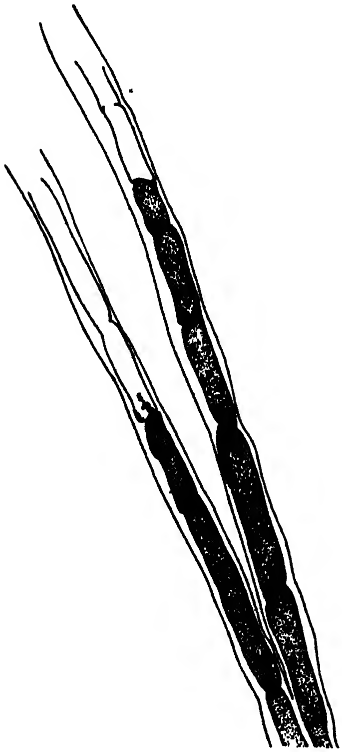

FIG. 1. Metaxylem strands from the nodal region of Co. 393 showing the ascent of Indian ink (by camera lucida X22·75)

nodal regions. The ink-suspension has abruptly stopped in the vessel at one of these constrictions where a septum is intact which effectively blocks the passage of this duct. In the same figure ink particles appear to have punctured the septum of the other xylem vessel, and are able to escape through it. It, therefore, indicates that a weak septum can be ruptured by a strong current of suspended particles. It naturally implies that in *Saccharum spontaneum* vascular strands have got rather tough septa which serve as effective barriers for the onward flow of the ink particles. Thus, it could be stated that a sugarcane variety would owe its red-rot resistance to the presence of strong septa in its vessels at the nodes, while susceptible ones would have either weak septa or no septa at all in this region. Again, it would be clear from Table I that a small percentage of ink-showing vascular bundles does occur even in the resistant varieties, and also that small linear-infections do appear in them. It only means that no sugarcane variety is fully resistant to the disease, but that a so-called resistant type is only comparatively less susceptible.

While explaining the probable cause of variation in resistance to red-rot in sugarcane, Edgerton and Carvajal [1943] point out that spores of the fungus are able to migrate very rapidly in the ducts of fibro-vascular bundles of certain varieties and with difficulty in others. This was due to the fact that most of the ducts of the latter varieties are not open in the nodes. Our studies from spore suspension experiment also revealed the presence of spores in the xylem vessels in the post nodal region of the stem of Co.213 (Fig. 2), and not in Co.393. This, perhaps, could be due to the ease with which spores could travel along the 'open' vascular bundles of Co.213. It is also significant that spores were not seen in the intercellular spaces indicating that these do not serve as passage for the migration of spores from one region to the other.

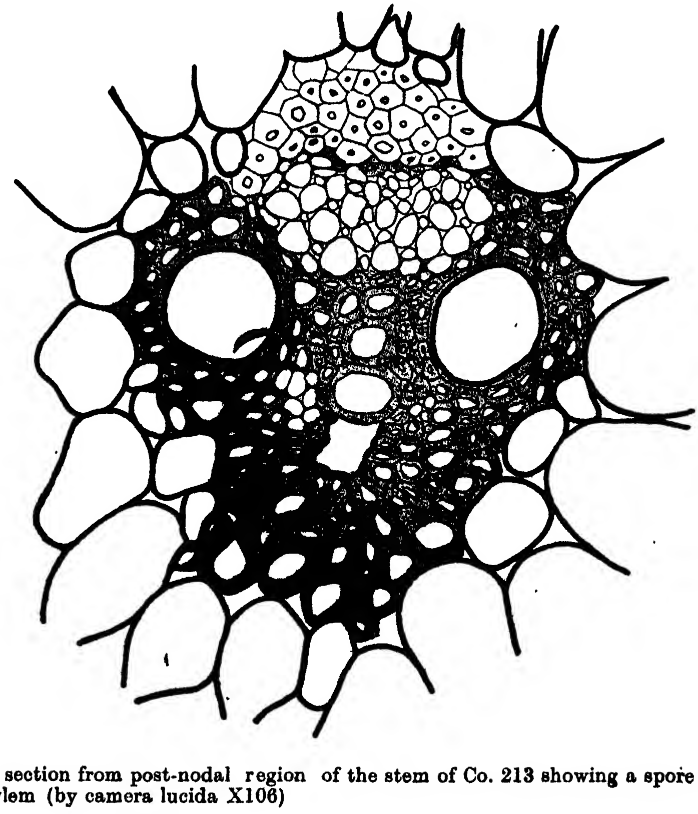

FIG. 2. Cross section from post-nodal region of the stem of Co. 213 showing a spore in the metaxylem (by camera lucida X106)

Indian ink particles, although very small (2 to $2 \cdot 5 \mu$) can be comparable to spores of the fungus (20μ long and 5μ broad) in as much as both of them are capable of being carried along with the transpiration current in the xylem vessels. The diameter of the xylem vessels has been found to be several times the length of the

spores. Therefore, these spores can move upwards like ink-particles within the vessels without difficulty and can pass through the nodes if the passage is ' open '.

In resistant varieties if red-rot infection starts, it generally remains confined to one or two internodes. In susceptible varieties, on the other hand, the infection spreads with ease from one internode to the other involving ultimately almost the whole length of the cane. If xylem vessels act as channels for rapidly conducting red-rot infection, as they appear to do, it can easily be assumed that varieties with ' closed ' vessels, i.e., with vessels having septa at the nodes, prevent the infection from spreading further. It, therefore, follows that a laboratory test with Indian ink suspension, as carried out in this investigation, would provide a quick method for determining the degree of red-rot resistance in sugarcane-varieties.

Summary.

Recent investigations suggest that rapid spread of red-rot in sugarcane is partly due to the migration of spores through the ' open ' vascular bundles at the nodes.

The immersion of cane tops in Indian ink suspension has shown that Indian ink particles are carried across the nodes through a larger number of vascular bundles in susceptible varieties as Co.312 and Co.213 than in the resistant varieties as Co.393, Co.453 and *desi dhor*. Examination of macerated vascular strand of the nodal region of Co.393 showed the presence of septa stopping the flow of ink through them.

The presence of red-rot spores has been found in xylem vessels of cane tops of Co.213 after immersion in a suspension of spores for 48 hours. This indicates that spores, like Indian ink particles, are carried through the xylem vessels and would be stopped by septa, if present.

These investigations suggest a quick laboratory test for assessing the degree of red-rot resistance in sugarcane varieties.

Acknowledgements

We are greatly indebted to Dr. B. K. Mukherji, Ph.D., D.Sc., Director, Main Sugarcane Research Station, Shahjahanpur, for his valuable suggestions and criticism throughout the entire course of this investigation. Our acknowledgements are due to Mr. D. N. Garg, Cane Mycologist, for supplying the liner infection data, and also to Mr. S. K. Arora, Artist, for the help rendered in making the camera lucida drawings. We are grateful to the Indian Central Sugarcane Committee for partly financing this Research Station where these investigations were carried out.

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CYTOGENETIC STUDIES ON CROSSES OF *GOSSYPIUM ANOMALUM* WITH CULTIVATED COTTONS I

[(*G. HIRSUTUM* × *G. ANOMALUM*) DOUBLED × *G. HIRSUTUM*]

By G. B. Deodikar,* Agricultural Research Station, Surat, India

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(With Plates VII, VIII and IX)

A NUMBER of interspecific hybrids and polyploids of *Gossypium* have been built up at the Agricultural Research Station, Surat, with *G. anomalum*, a wild African diploid species, as one of the parents. These are characterized by their vigorous and rapid growth, profuse scaffolding of branches, general healthiness and tolerance to some of the diseases and pests common to cultivated cottons. *G. anomalum*, by itself, is resistant to red mites, leaf roller, bud worm, semilooper and other leaf eating caterpillars [Margabandhu, 1941] and is almost immune from black-arm or angular leaf-spot disease caused by *Bacterium malvacearum* [Anson *et al* 1945]. The leaves of *G. anomalum* bear profuse growth of epidermal hairs on their laminae and veins—a character which is known to contribute to jassid resistance. In the case of fertile derivatives from *G. anomalum* crosses, having normal seed setting, the fibre shows some exceptional good qualities as regards length, fineness, strength, lustre and smooth silky feel. In spite of all these good qualities, however, the synthetic types have some undesirable features such as complete or partial sterility, small boll-size and brownish meagre lint closely matted round the seedcoat, which renders ginning operation difficult. Though on these grounds these types as such are not likely to be of immediate economic use, they are nevertheless useful for further hybridization work. Attempts are, therefore, being made at Surat, for the past several seasons, to transfer some of the useful characters of *G. anomalum* specified above, to cultivated cottons, through a series of appropriate crosses.

The present paper summarises the cytological studies on the first backcross generation of [(*G. hirsutum* × *G. anomalum*) Doubled × *G hirsutum*] and discusses the possible results in the light of its meiotic chromosome behaviour. The object of these crosses was to incorporate certain desirable traits of *G. anomalum* into the genotypic background of the cultivated tetraploid cottons. Beasley and Richmond [1943] have reported similar attempts to transfer *anomalum* characters to upland cottons.

*Now at Cytogenetic Laboratory, Economic Botany Department, College of Agriculture, Poona.

N

MATERIAL AND METHODS

Co2, an improved strain of acclimatised *G. hirsutum* (2n=52) [AA DD] cotton from Coimbatore, South India, was crossed with *G. anomalum* (2n=26) [BB] and the chromosomes in the sterile allo-triploid (2n=39) [ADB] thus obtained, were doubled by means of colchicine giving a fertile hexaploid (2n=78) [AA DD BB] [Amin, 1941, Iyengar, 1944, Patel *et al.*, 1946]. This hexaploid [(*G. hirsutum* × *G. anomalum*) F1 Doubled] [AA DD BB] was backcrossed to *G. hirsutum* (Co2) [AA DD] using the former as seed parent and as a result, 49 seeds were secured. Out of these, only 19 germinated and developed into mature plants, which formed the first back-cross population. In view of their origin from the allo-hexaploid and allo-tetraploid parents denoted above, which involved the fusion of (ADB) female gametes with (AD) male gametes, these first backcross individuals were expected to be allo-penta-ploids with [AA DD B] as their genomic constitution.

The seedlings were raised as pot-cultures during their earlier period of growth in the glass house and after collection of root tips, were transplanted in the field. Flower buds were collected during December to February 1946-47 between 11 to 12 a.m. on bright sunny days. They were fixed in Carnoy for two to four hours, treated in a mixture of concentrated HCl and 95 per cent alcohol in equal proportion for five minutes at 45°C., repeatedly rinsed in 95 per cent alcohol and temporarily stored in alcohol of the same strength. Anthers at the proper stages were smeared in acetocarmine containing a trace of ferric chloride. Slides were sealed with paraffin and these temporary mounts were used for microscopic examination. The root tip material did not give sufficient number of clear chromosome plates for somatic counts. Since the aceto-carmine preparations of P.M.C. were very clear, these were used both for determining the chromosome number (2n) and for their meiotic behaviour.

All chromosome drawings (Plate VII, figs. 1-5; Plate VIII, figs. 6-8; Plate IX, figs. 9-10) were made at bench level with the aid of a *camera lucida* using 1·8 achromatic oil immersion objective (95 ×) and compensating ocular (15 ×). In the case of other drawings (Plate IX, figs. 11-18) the same ocular was used in combination with a low power objective (10 ×).

OBSERVATIONS

The backcross population was more or less uniform except for a few morphological differences on the basis of which all the plants could be broadly classified into the following two groups :

(*a*) Plants with long, loose scaffolding, with dark green, broad, convex, hairy leaves having 3 to 5 well separated lobes. Pot-cultures 12/2, 3, 10, 17, 25, 26, 28, 30, 39 and 45 belonged to this class.

(*b*) Plants with short, compact scaffolding with light yellowish green, medium or small, concave, intensely hairy leaves having 3 to 5 lobes with overlapping margins. Pot-cultures 12/6, 9, 14, 23, 27, 35, 40 and 42 belonged to this class. The relative proportion of plants belonging to the above two classes was 10 : 9 or 1 : 1.

An examination of 18 plants for chromosome conjugation at the first metaphase during meiosis gave the following mean values (Table I).

EXPLANATION OF PLATE VII

FIG. 1. Diakinesis ; 11 I+27 II (2n=65)
FIG. 2. M-phase I ; 13 I +19 II+2 III+2 IV (2n=65)
FIG. 3. M-phase I ; 11 I ± 18 II + 3 IV+1 VI (2n=65)
FIG. 4. M-phase I ; 11 I+9 II+1 III+7 IV+1 VI (2n=66)
FIG. 5. M-phase I ; 7 I+19 II+4 IV+ 1 VI (2n=67)

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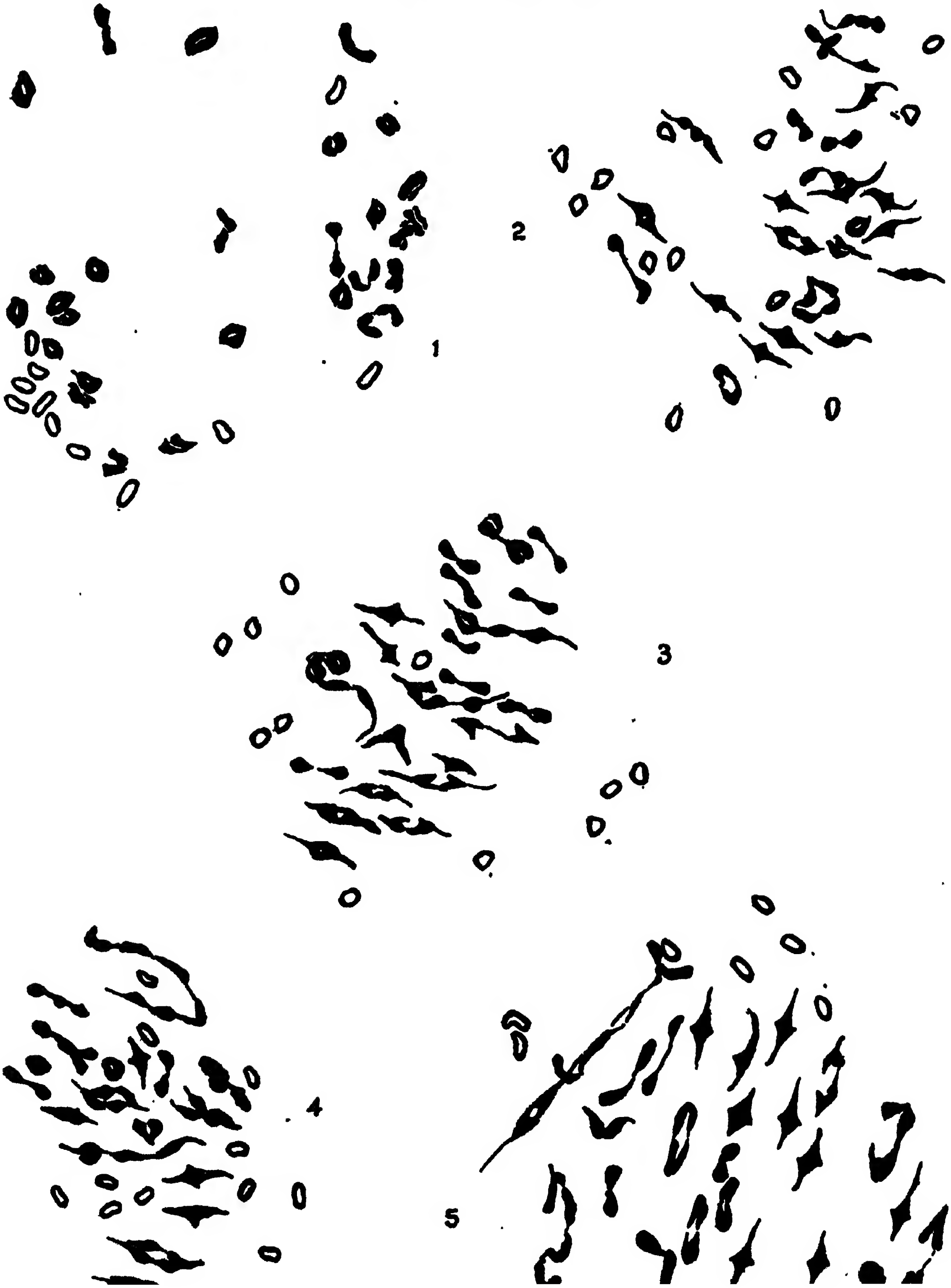
CYTOGENESIS IN [(*G. HIRSUTUM* × *G. ANOMALUM*) DOUBLED×*G. HIRSUTUM*]



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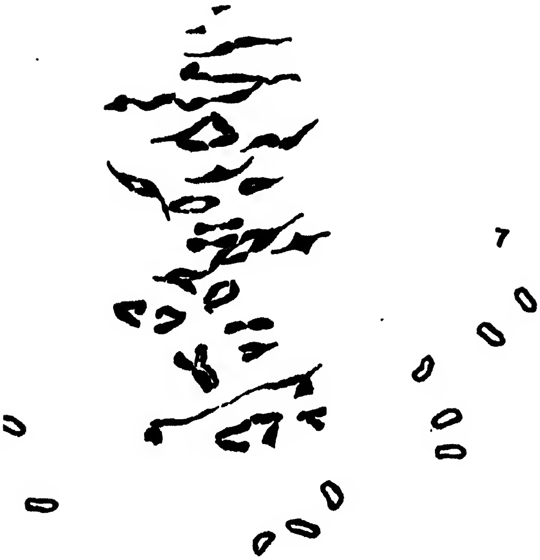

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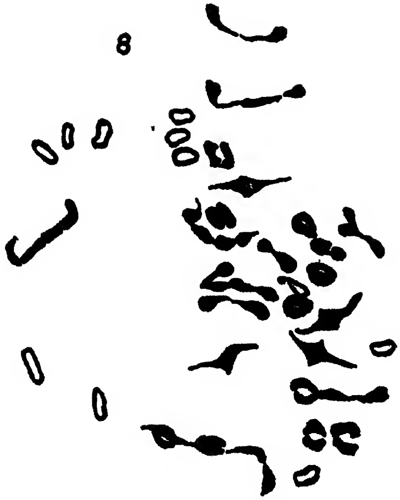

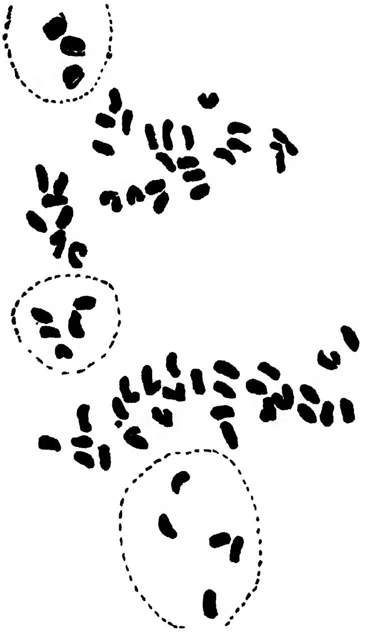

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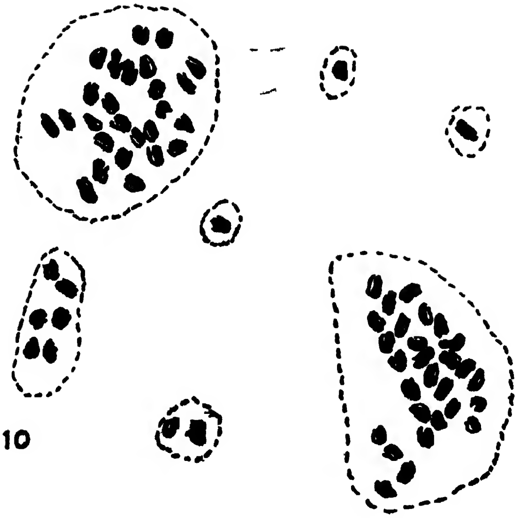

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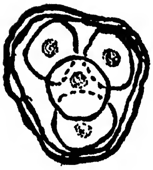

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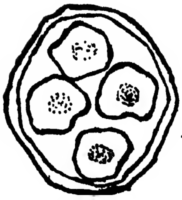

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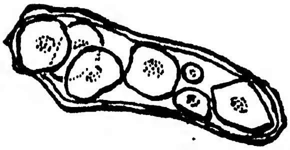

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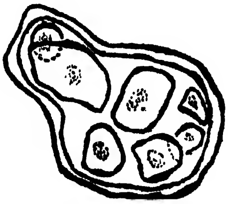

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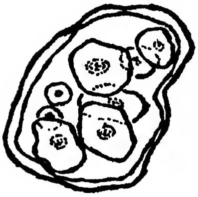

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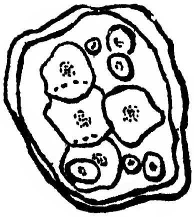

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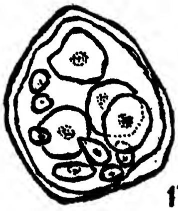

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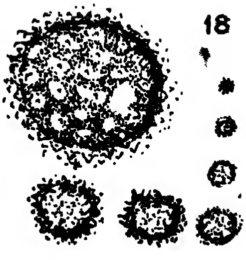

EXPLANATION OF PLATE IX

FIG. 9. Telophase I ; Showing 2 major and 3 minor groups containing 28, 27, 5, 5 and 3 chromosomes each (2n=68). Precocious deposition of cell wall around the three minor groups. The minor group containing 3 univalents showing longitudinal split

FIG. 10. M-phase II ; Showing 2 major and 5 minor groups containing 28, 26, 6, 2, 1, 1, 1 chromosomes each (2n=65). Cell wall being deposited around each group

FIGS. 11 to 12 showing P. M. C. with normal tetrad stage

FIGS. 13 to 17 showing P. M. C. with abnormal tetrad stages containing 7 to 11 microspores+micronuclei

FIG. 18 showing pollen grains, big and small with intergrades

TABLE I

Chromosome conjugation in the first backcross individuals [(G. hirsutum G. anomalum) F_1. *Doubled* G. hirsutum]

Serial number	Pot-culture number	Number of P.M.C. at m-phase studied	Mean chromosome conjugation					
			Univalents	Bivalents	Trivalents	Quadrivalents	Hexavalents	Mean chromosome number (2n)
1	12/6	4	15·25	17·50	..	2·25	1·00	65
2	12/35	3	10·00	19·67	..	3·00	0·67	65
3	12/40	6	10·00	19·34	0·17	3·33	0·50	65
4	12/42	7	9·86	17·43	0·71	3·86	0·57	65
5	12/23	8	10·88	19·75	..	2·88	0·75	66
6	12/25	10	10·50	19·10	0·40	2·70	0·90	66
7	12/26	6	10·17	18·67	0·84	2·50	1·00	66
8	12/38	5	10·20	20·20	..	2·60	0·80	66
9	12/10	7	10·57	17·00	1·29	3·15	1·00	67
10	12/30	7	10·14	17·71	..	3·86	1·00	67
11	12/45	5	7·40	18·80	..	4·60	0·60	67
12	12/2	8	10·75	18·50	1·25	3·00	0·75	68
13	12/3	5	11·00	19·40	0·40	2·80	1·00	68
14	12/14	3	10·00	19·00	..	3·50	1·00	68
15	12/17	1	9·00	15·00	1·00	5·00	1·00	68
16	12/27	7	11·43	19·30	0·51	2·71	0·86	68
17	12/28	5	10·20	19·80	0·40	3·00	0·80	68
18	12/9	4	11·00	18·75	..	3·25	1·25	69
Mean conjugation in B_1 individuals with the same (2n) chromosome numbers		20	11·28	18·48	0·22	3·11	0·68	65
		29	10·44	19·43	0·31	2·67	0·86	66
		19	9·37	17·84	0·43	3·87	0·87	67
		29	10·40	18·50	0·59	3·33	0·90	68
		4	11·00	18·75	..	3·25	1·25	69

It will be seen from Table I that the chromosome numbers of individual plants in the backcross population occur as 65 + 1 to 4, which is in conformity with their allo-pentaploid constitution (AA DD B). During meiosis, univalent and multivalent associations of 2, 3, 4 and 6 chromosomes appeared in variable proportions. Majority of chromosomes associated as bivalents. The mean number of trivalents and hexavalents showed a progressive increase with increase in chromosome number from 2n=65 to 69. This possibly indicates that the supernumerary chromosomes which were in excess of the normal pentaploid complement of 65, mostly participated in such tri-and hexavalent associations. Quadrivalents and hexavalents showed chromatin bridges during their anaphasic separation (Plate VII, figs. 4-5 ; Plate VIII, figs. 6-7). Number of univalents varied over a narrow range from 9 to 11 per P.M.C. in most cases except in pot-culture 12/6 where their mean number is too high (15·25) and in pot-culture 12/45 where it is too low (7·40). Univalents could be easily distinguished from the rest of the chromosomes at m-phase due to their darker staining, relatively larger size and random orientation in a scattered manner outside the main group of conjugated chromosomes at m-phase. It appears, that they undergo comparatively less linear contraction and therefore, their individual morphological features such as satellites or constrictions were sometimes more clear than in the rest of the chromosomes (Plate VII, figs. 1-5; Plate VIII, figs. 6-8). Throughout anaphase and telophase of the first division, these univalents either remained static at the positions originally occupied during m-phase or moved at random and lagged behind. As a result of this, in addition to the two major groups of separating chromosomes, there were also minor groups at ana and telophases formed by the incorporation of the scattered univalents (Plate IX, fig. 9). These groups gradually lost their chromaticity during interphase and again reappeared at the second meiotic division (Plate IX, fig. 10). Analysis of 14 pollen mother cells taken from 10 different pot-cultures showed at telophase I or metaphase II, the following distribution of chromosomes in groups (Table II).

TABLE II

Chromosome grouping at first telophase or second m-phase

Serial number	Number of groups	Number of chromosomes in each group	Total (2n)
1	3	38+26+3	67
2	3	33+31+3	67
3	3	34+29+4	67
4	3	39+26+1	66
5	3	39+26+1	66
6	4	33+32+2+1	68
7	4	29+28+6+4	67
8	5	33+23+5+4+3	68
9	5	34+31+2+1+1	69
10	5	28+27+5+5+3	68
11	5	30+29+6+2+1	68
12	6	32+28+2+2+1+1+1	66
13	7	30+27+3+2+2+1+1	66
14	7	28+26+6+2+1+1+1	65

As shown in Table II, the number of major and minor groups varied from 3 to 7. Univalents in the minor groups frequently showed precocious longitudinal split (Fig. 9). There was also precocious deposition of cell wall round some of the minor groups which process might begin at late anaphase or early telophase of the first division (Fig. 9). In the case of the two major groups of previously conjugated chromosomes, such wall was seen deposited usually after the completion of the second meiotic division. As a result of such internal free cell formation, there were usually four microspores of normal size together with a variable number of abnormally small micronuclei enclosed within the wall of the same pollen mother cells (Figs. 11 to 17). Table III gives the frequency of P.M.C. with different numbers of micronuclei.

Table III

Frequency of P.M.C. containing microspores + micronuclei

Number of microspores + micronuclei per pollen mother cell	1	2	3	4	5	6	7	8	9	10	11	
Number of P.M.C.	2	8	24	146	92	72	68	30	10	5	1	*Total*=458

The number of microspores+micronuclei per P.M.C. therefore, varied from 1 to 11, modal value corresponding to 4. The resulting pollen grains showed corresponding range of variation in their size from large to small with intergrades (Fig. 18).

The plants of the first backcross generation gave only a stray setting of bolls and these in turn contained only a few healthy seeds. About 45 seeds thus obtained were sown in the next season and the progenies were under further observation.

INTERPRETATION

Synthetic hexaploid [AA DD BB], the seed parent in the cross from which the first backcross individuals were derived, gives more or less uniform (ADB) gametes due to regular autosyndetic pairing of the identical duplicated chromosomes [Beasley, 1942, Iyengar, 1944]. Co2, the pollen parent, is also relatively homozygous, having been isolated by pure line selection. This possibly explains the absence of any wide range in morphological variations among the backcross individuals studied here. The hexaploid (AA DD BB) shows slight meiotic irregularities by way of rare univalent and multivalent associations [Beasley, 1942 ; Iyengar, 1944]. These small meiotic irregularities may be responsible for the slight variation in chromosome numbers of the backcross individuals within a close range of (65 + 1 to 4).

Since the allopentapliod backcross individuals have the genomic constitution (AA DD B), theoretically their meiotic conjugation should consist of 26 bivalents and 13 univalents (13 pairs of AA + 13 pairs of DD + 13 chromosomes of B set

appearing as univalents). It will be seen from Table I that the expected number of univalents was nearly realised in some cases but in other respects the actual mode of conjugation considerably deviates from the theoretical expectations due to formation of multivalents. Trivalents and quadrivalents may be formed as a result of allosyndesis due to expression of partial homologies between A, B and D sets. This has been reported in interspecific *Gossypium* hybrids of the type AB, BD and AD by several authors. In the case of backcross individuals with more than 65 chromosomes, hexavalents may be formed due to conjugation of supernumerary homologues. But such hexavalents have been observed even in the case of individuals with 65 chromosomes (Table I). Association of 6 chromosomes in such cases is difficult to understand but it can be explained in the light of the following facts which have been so far observed.

(1) Chromosomes of *Gossypium* may show intrahaploid pairing under abnormal conditions of meiosis [Skovested, 1933 ; Webber 1938 ; Beasley, 1942].

(2) Cultivated amphidiploid cottons (AADD) rarely show small proportion of quadrivalents due to allosyndetic pairing between A and D sets [Webber, 1934].

(3) A and D sets do not ordinarily pair with each other but both of them can pair with B to a variable extent [Skovested, 1937; Webber, 1939; Silow, 1941].

B-chromosomes of *anomalum*, therefore, act as a bridging link between A and D chromosomes so that all these three sets may occasionally enter into multivalent associations. Formation of hexavalents can, therefore, be explained as a result of possible operation of one or more of these factors. The fact that chromatin bridges are formed during their anaphasic separation, supports the above explanation since it implies that the chromosomes participating in such multivalent associations are not identical in all respects but have undergone considerable linear differentiation through inversions and other forms of structural changes.

Formation of micronuclei through internal free-cell formation may lead to interesting consequences. It has the effect of isolating abnormal univalents possibly from B set and prevent them from getting mixed up with other chromosomes that have undergone pairing. Such elimination may result in correspondingly minimising the irregularities of the gametes that have developed from the paired chromosomes, and thus render them less non-functional. Partial seed-setting obtained on these sterile allopentaploids may perhaps be attributed to chance fusion of such less irregular gametes.

Discussion

Individual plants in the first backcross generation have been again backcrossed to the *hirsutum* parent and this process will be continued until chromosomally balanced types combining the desirable economic qualities are secured. In the light of the meiotic chromosome behaviour of the first backcross individuals studied here, we may expect the following results to occur in the course of such recurrent backcrossing :

(*a*) *Exchange of genes between A and D sets of cultivated New World Cottons* (*AA DD*). A and D chromosome sets in the New World Cottons (AA DD) seldom show allosyndetic pairing so that chances of gene exchange among them are very remote. Since the B-chromosome set may partially pair both with A and D sets, it can serve as a medium to bring about such gene exchange between A and D sets, through its alternate pairing in successive generations. Such internal transfer of genes among A and D sets does not involve any quantitative change. But it may possibly lead to qualitative changes due to transfer of a few genes to new locations within the frame work of the same genomic constitution. The 'position effects' of similar nature are well known in the case of mutant 'Bar' genes in *Drosophila* [Sturtevant, 1925].

(*b*) *Transfer of anomalum genes to the genotype of the cultivated 52 chromosome cottons*. *Anomalum* genes may get transferred to A or D chromosomes or to both. Such transfer will be directly proportional to the number of AB or BD pairs formed and the frequency of chiasmata along these pairs. Skovested [1937] and Webber [1939] have studied the meiosis in hybrids of the type (AB) and (BD) and have found that the mean conjugation in the former is about 11 to 12 bivalents and in the latter about 5 to 6 bivalents. This implies higher affinity of *anomalum* B set to A than to D genome. Therefore, in the present case, where both A and D sets are available for pairing with B, there is relatively greater chance of *anomalum* genes being transferred to A set than to D. It will be seen from Table I that the mean number of univalents during meiosis is the highest (15·25) in the case of pot-culture 12/6 and lowest (7·40) in the case of pot-culture 12/45. This implies that the number of AB or BD pairs formed is minimum in the former case and maximum in the latter. On the basis of the above considerations, therefore, for the purpose of transference of *anomalum* genes to the *hirsutum* cottons, there is greater chance of success being achieved if we use a type like 12/45 showing more pairing instead of a type like 12/6 which shows less pairing. As regards the possible factors which may be responsible for such minor plant to plant variations in the degree of pairing in a population having the same genomic constitution (AA DD B), we can only surmise. There are many instances of synthetic hybrids and polyploids of *Gossypium* wherein the degree of meiotic pairing in materials with identical genomic constitution as observed by the same or different workers show considerable divergence. But the fact that such minor plant to plant variations exist in such populations, provides the possibility of utilizing them in a manner so as to serve the objective in view. Perhaps it is such variations which provide scope for continuous selection in the successive generations of synthetic autotetraploids [Frolova, 1946] or in synthetic allopolyploids containing homologous chromosomes in multiples [Armstrong *et al* 1947].

(*c*) *Substitution of A and D chromosomes by their homologues from the anomalum B set*. Since AB or BD pairs have random orientation during anaphasic separation, we cannot expect all the B chromosomes in such pairs going to one pole and their counterparts going to another. This must, therefore, lead to formation of some 26 chromosome gametes wherein some of the A or D chromosomes may be replaced by their B homologues. Chance fusion of such gametes may lead to formation of 52

chromosome cottons wherein a few of the members of the normal (AA DD) set may be substituted by their homologues from *G. anomalum*.

(*d*) *Addition of anomalum chromosomes to the (AA DD) complement of cultivated tetraploid cottons.* General course of meiosis in the first backcross individuals described before is such that it is likely to form some gametes having full AD complement plus one or more univalents from the B set. Chance fusion of such gametes will give individuals having (1) full (AA DD) complement plus *anomalum* single chromosomes, (2) full (AA DD) complement plus *anomalum* chromosomes in homologous pairs. It has been stated before that as a result of stray setting on the 19 first backcross individuals, 45 seeds have been secured. These seeds when germinated should give rise to plants of both the types under (1) and (2) specified above. Seeds obtained as a result of second backcrossing to *hirsutum* can only give rise to individuals of the type (1) specified above and at least one generation must intervene before the single *anomalum* chromosomes can appear as homologous pairs through selfing.

In the course of such recurrent backcrossing, one or more of the possible changes described above, may occur either separately or all together. There is every possibility of changes under (A) taking place but it will not be possible to study these changes individually in isolation due to difficulties involved in this case, of distinguishing such 'position effects' from other concurrent effects due to the added *anomalum* genes. Changes taking place under (B) are likely to be of most practical utility. If a stable and well balanced type is to be aimed at as a final product, all that can be expected from such wide interspecific crosses is the transference of a few desirable genes which can be harmoniously incorporated into the genetic frame work of the recurrent parent. Any of the *anomalum* chromosomes may pair either with A or D or both and yet it may not be possible to effect the transfer of some of its desirable genes if they are located at such loci along the length of pairing chromosomes where crossingover is impossible. In such cases *anomalum* characters can be incorporated in the recurrent parent by substituting A or D chromosomes by their B homologues carrying the desired genes as described under (C). In such interspecific differences, however, homology of the substituted chromosomes does not imply its genetic identity with the original chromosomes so that the former cannot be harmoniously incorporated within the genomic framework of the recurrent parent without disturbing its initial specific balance. This situation sometimes leads to either gametic or zygotic elimination of the substituted chromosomes [East, 1927]. In such an event, the only way to incorporate the desirable *anomalum* characters in the recurrent parent is by the addition of *anomalum* chromosomes in homologous pairs as described under (D).

Such 'alien substituted races' and 'alien addition races' described under (C) and (D) respectively, have been already obtained in the case of wheat, tobacco and a few other crops [Kattermann, 1938 ; Nishiyama, 1939 ; O'mara, 1940 ; Gerstel, 1945 ; Clayton, 1947, etc.]. Gerstel [1945] succeeded in adding an entire chromosome pair from *Nicotiana glutinosa*, carrying resistance to the mosaic virus disease, to the unaltered complement of *N. tabacum*. In a similar manner, Clayton [1947] succeeded

in evolving cultivated tobacco, resistant to the severe bacterial disease (wild fire) caused by *Pseudomonas tabaci* and *P. angulata*, by using the wild species *N. longiflora* which carries immunity genes. Many of these synthetic types are meiotically stable and true-breeding and are, therefore, useful as breeding stocks for the improvement of cultivated forms. Therefore, such synthetic derivatives with substituted or added chromosomes have not only theoretical value but practical utility as well.

By using the first backcross individuals studied here as pollen parents and *G. hirsutum* (Co2) as seed parent, a second backcross population was raised to maturity during the current season. Cytological study of these second backcross individuals has shown that they actually contain one to three *anomalum* chromosomes (2n=52+1 to 3) which could be identified either as substituted or added, by their characteristic behaviour during meiosis. Since the study of this second backcross generation has revealed certain points of theoretical and practical importance, these results will be presented in detail later.

Cotton workers from Coimbatore and the Punjab in India have already proved the utility of *G. anomalum* for improving the economic characters in the cultivated *Arboreum* cottons (2n=26). But it is not yet known whether *G. anomalum* can be similarly utilised for the improvement of some of the economic characters in the cultivated New World cottons (2n=52). The present investigations are aimed at exploring the possibilities in this direction.

SUMMARY

Synthetic hybrids and polyploids of *Gossypium* involving the African wild diploid species *G. anomalum* are remarkable in respect of rapidity of growth, vigour, healthiness and tolerance to some of the diseases and pests on cottons. Their fibre is strong, fine and lustrous with smooth, silky feel. With a view to transferring these economically useful characters to cultivated tetraploid cottons, a synthetic hexaploid [(*G. hirustum* × *G. anomalum*) F_1 Doubled] is being repeatedly backcrossed to the *hirsutum* parent.

The chromosome numbers in the first backcross individuals occur as (2n=65+0 to 4) as expected on the basis of their allo-pentaploid genomic constitution (AA DD B). In the case of individuals with normal pentaploid chromosome number (2n=65), the mean meiotic conjugation consists of 11·28 I + 18·48 II + 0·22 III + 3·11 IV + 0·68 VI. Among other contributary factors, formation of allosyndetic multivalents through the bridging influence of B chromosomes, possibly accounts for the discrepancy between the expected and actual modes of meiotic pairing. Multivalents show chromatin bridges during their anaphasic separation. Majority of the *anomalum* chromosomes appear as univalents scattered at random in isolated groups, each of which develops into a micronucleus, variable in size and number (1 to 11 per P.M.C.), by a process of internal free-cell formation.

In the course of recurrent backcrossing in the present case, following results may be expected:

(1) Exchange of genes between A and D sets of cultivated New World cottons (AA DD), through the bridging influence of *anomalum* B chromosomes.

(2) Transfer of *anomalum* genes to A and D chromosomes.

(3) Substitution of A and D chromosomes by their homologues from the *anomalum* B set.

(4) Addition of *anomalum* chromosomes to the (AA DD) complement of cultivated tetraploid cottons.

These possibilities are discussed in short in the light of the meiotic chromosome behaviour of the first backcross individuals.

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INVESTIGATIONS ON THE 'BAD OPENING' OF BOLLS IN SIND-AMERICAN COTTONS IN SIND

I. CAUSES AND THE REMEDIAL MEASURES FOR BAD OPENING*

†By R. H. Dastur, Plant Physiologist, Indian Central Cotton Committee, Bombay

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With the introduction of perennial irrigation in Sind after the construction of the Lloyd Barrage in 1932, the acreage under American cotton crop in Sind had considerably increased, so much so that nearly 90 per cent of the total cotton crop of 8,44,597 acres in 1946-47 was American. The cotton area in Sind can be divided into three tracts on account of small differences in the climatic conditions prevailing in each: (i) the South and East tract comprising of Tharparkar and lower half of the Hyderabad district, (ii) the Middle Sind comprising of Nawabshah district and (iii) the North Sind comprising of Larkana district and some parts of Sukkur district. Of the three tracts, the first two are situated on the left bank of the Indus river, while the third tract is on the right bank. The first was by far the most important cotton tract where major portion of the total American cotton crop was grown.

There are small but important differences in the climatic conditions in these tracts. South and East Sind are characterized by a milder climate than the Middle and the North Sind. In the South and East Sind the temperatures are as high as in the Middle or the North Sind during the months of April and May, but they drop appreciably towards the end of June in the South Eastern parts as compared with the temperatures prevailing in the other two tracts where high temperatures continue to prevail until September. The relative humidity during the day is also higher during the growing period in the South and East Sind than in the Middle and the North Sind. Climatically the South and East Sind was, therefore, different from the other two zones, the latter resembling in climatic conditions the South-western tracts of the Punjab. The differences in climatic conditions in the three cotton growing areas of Sind were responsible for the differences in the sowing and harvesting time for the cotton crop. The crop was planted and harvested in the South and East Sind earlier than in the Middle and the North Sind or in the Punjab. The climatic conditions in the North Sind were still more severe than in the Middle Sind.

The Punjab-American varieties were first imported into Sind in 1923-24 and various selections were made of which 4F/98 and *Sind Sudhar* proved to be suitable

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†R.H. Dastur was formerly Professor of Botany, Royal Institute of Science, Bombay.

for growing in Sind. These strains were given to the cultivators in 1933-34 and the acreage under these strains increased every year since then, with a consequent reduction in acreage under the *desi* types. Later on, another strain named M4 was produced at Mirpurkhas by pure line selection, from another Punjab-American strain called N. T. 21 and it entered into large scale cultivation in the year 1940. This strain was earlier in maturity, gave higher yield and lint out-turn but was coarser than *Sind Sudhar*. M4 has now become a popular strain with cotton growers in Sind.

The American cotton crop in Sind has been reported to suffer from two types of physiological diseases ever since it entered into large scale cultivation. These were 'bad opening' of bolls and the red leaf blight. The 'bad opening' of bolls indicated the prevalence of *tirak* as in the case of the Punjab-American cottons though the periodic failure of American cottons accompanied by intensification and spread of *tirak* as in the Punjab have not been reported from Sind. The 'bad opening' of bolls has been reported in the year 1932 by Barakzai [1938] in his Report of Sind Physiological Scheme which was partly financed by the Indian Central Cotton Committee.

It was, therefore, undertaken to investigate the causes that produced 'bad opening' of bolls and to remedy it by applying the same measures that were successful in the Punjab [1946]. The investigations on the red leaf disease have already been published [Dastur and Singh, 1947].

INVESTIGATION

Two soil types associated with 'bad opening' of bolls. During the cotton season of 1942 several fields were noticed in the different parts of Sind where the American cottons showed symptoms of 'bad opening' of bolls which contained immature seeds with poor quality of lint. The drooping and shedding of leaves in some fields were found to have been associated with 'bad opening' of bolls. These symptoms resembled *tirak* symptoms described for the Punjab-American cottons in the Punjab on soils with saline subsoil [Dastur and Singh, 1942] The yellowing and shedding of leaves was also a feature of the Sind-American cottons in Sind and these symptoms indicated light sandy lands deficient in nitrogen. It was, therefore, undertaken to determine, if the same two soil types, viz. (i) soils with saline subsoils and (ii) light sandy lands deficient in nitrogen, were associated with 'bad opening' of bolls in Sind as was found to be the case in the Punjab [Dastur, 1946].

Analysis of the soil upto a depth of six feet from fields, where drooping and the shedding of leaves accompanied by 'bad opening' of bolls was found to occur in different cotton tracts, was made and it was found that such fields contained abnormal quantities of soluble sodium salts in the subsoils as was the case in the Punjab. Results of soil analysis for two places are given below in Table I.

TABLE I

Soils with saline subsoils

	Nasirabad Estate (Kinjhejhi)					Cotton Botanist Farm (Mirpurkhas)						
Depth in feet	Total salts per cent	Soluble calcium per cent	Soluble sodium per cent	Exchange-able calcium m.e.	Exchange-able Na+K m.e.	*p*H	Total salts per cent	Soluble calcium per cent	Soluble sodium per cent	Exchange-able calcium m.e.	Exchange-able Na+K m.e.	*p*H
1st foot	0·063	0·011	0·006	10·8	1·4	8·3	0·080	0·013	0·006	8·4	0·8	8·1
2nd foot	0·096	0·015	0·014	11·6	1·4	8·2	0·256	0·024	0·048	7·6	1·4	8·0
3rd foot	0·162	0·023	0·033	10·8	1·6	8·1	0·454	0·025	0·146	6·0	0·4	8·0
4th foot	0·174	0·022	0·033	9·2	1·2	8·1	0·435	0·015	0·122	4·8	2·6	8·3
5th foot	0·330	0·031	0·046	6·4	1·0	8·0	0·497	0·017	0·132	4·4	3·2	8·2
6th foot	0·554	0·051	0·088	8·8	1·8	7·9	0·537	0·017	0·136	4·8	2·8	8·2

Soluble sodium was found to be higher than soluble calcium while exchangeable sodium was present in some cases but not in others. Similar results were obtained from the analysis of the soil samples taken from fields where *tirak* had occurred in other parts of Sind.

Light sandy soils were found to be widely distributed in Sind. In chemical and physical properties they resembled the light sandy lands met with in the Punjab [Dastur and Samant, 1942]. In many cases the clay fraction was lower than 10 per cent (Table II). Such light sandy soils were found to contain normal quantities of soluble salts in some cases while in some cases they were found to contain abnormal amounts of sodium salts. Thus, both *tirak* promoting conditions were also found associated together as in the Punjab.

TABLE II

Light sandy soils with normal subsoils

Depth in feet	Total salts per cent	Soluble calcium per cent	Soluble sodium per cent	Clay per cent	Silt per cent	Sand per cent
1st foot	0·063	0·010	0·008	7	14	76
2nd foot	0·060	0·010	0·007	11	17	72
3rd foot	0·068	0·009	0·005	9	26	64
4th foot	0·066	0·013	0·007	9	34	56
5th foot	0·093	0·014	0·007	15	39	45
6th foot	0·080	0·014	0·006	23	54	22

The crop on light sandy land showed premature yellowing and reddening of the leaves in the months of August and September. The red leaf blight generally developed on such lands and the investigations on this physiological 'disease' have already been described in a previous contribution [Dastur and Singh, 1947].

In addition to the above mentioned soil types found in Sind there were soils which contained a very high proportion of clay varying from 30 to 50 per cent different layers. Such soils were not found suitable for cotton growth as the crop remained small and stunted. These soils were also found unsaturated with bases.

Amelioration of 'bad opening' of bolls.—As late sowing was found to be a common remedy for *tirak* occurring on both soil types in the Punjab, [Dastur and Singh, 1940] it was undertaken to try out this measure to ameliorate 'bad opening' of bolls occurring in the Sind-American cottons in Sind. It was necessary to arrange experiments on the two soil types in the different parts of Sind as the normal sowing period for cottons differed in the three different tracts. It was decided to go beyond the normal sowing period by about one month so as to determine the remedial effect of late sowing on the 'bad opening' of bolls as compared with the 'bad opening' occurring in the normally sown crop. Three to four sowing dates were, therefore, included as treatments in each experiment. M4, L. S. S. and *Sind Sudhar* were the three varieties normally grown in Sind and these were included in the experiments. Besides, the different Punjab-American cottons like 289F/K25, 289F/124 and 289F/199 were also included in some of these experiments. In some experiments laid out on light sandy lands the application of sulphate of ammonia was included as a separate treatment to study the remedial effect on 'bad opening' of bolls of the application of sulphate of ammonia to light sandy lands. The effect of application of an extra irrigation during fruiting period to heavy sandy loams with saline subsoils on 'bad opening' of bolls was also studied in some experiments in view of the results obtained in the Punjab [Dastur and Singh, 1940]. All experiments were designed employing modern technique as was done in the Punjab. The experiments were conducted during the period 1943 to 1946.

The boll weight determinations were made from randomised plants in each sub-plot of all the replicates at each picking. The boll weight results were statistically analyzed.

The boll weight determinations were made in 16 such experiments and the results of four of these experiments are given in Table III.

Cotton sowings in South and East Sind normally began by the third week of March and terminated by the end of April. So May and early June sowings along with March and April sowings were also included in the experiments conducted in this tract. It was found that later sowings gave significantly higher boll weight than the normal sowings (Table III), both at Kinjhejhi and Denisar Estate which were situated in the South Eastern parts of Sind. M4 strain gave significantly higher boll weight than *Sind Sudhar* or L. S. S.

The normal sowing period for the Middle Sind was between the middle of May and the middle of June; so late June and July sowings were included along with normal sowings in the experiments conducted in that tract. The results obtained in the two sowing date experiments conducted at Sakrand and at Pad Idan in this tract are given in the Table III. The end of June and July sowings gave significantly higher boll weights than the first two sowings at Sakrand. Similarly at Pad Idan the first two sowings suffered significantly more from 'bad opening' of the bolls than the last two sowings.

TABLE III

The remedial effect of late sowing on tirak as determined by the increase in weight of seed cotton per boll in gm.

Experiment No. 7 — Kinjhejhi (1943)

Variety	Sowing dates				
	29 March	19 April	9 May	30 May	Mean (±0·048)
M4	2·45	2·84	3·25	3·71	*3·06*
Sind Sudhar	1·72	2·11	2·05	2·79	*2·17*
L. S. S.	2·24	2·39	2·49	2·92	*2·51*
Mean (±0·062)	*2·14*	*2·45*	*2·60*	*3·14*	..

Experiment No. 2 — Denisar Estate (1943)

Variety	Sowing dates				
	2 April	23 April	16 May	3 June	Mean (±0·047)
M4	2·43	2·86	3·30	3·55	*3·04*
Sind Sudhar	2·57	2·74	3·15	3·25	*2·93*
L. S. S.	2·59	2·72	2·88	2·89	*2·77*
Mean (±0·072)	*2·53*	*2·77*	*3·11*	*3·23*	..

Experiment No. 24 — Sakrand (1943)

Variety	Sowing dates				
	14 May	3 June	24 June	17 July	Mean (±0·09)
M4	2·71	2·77	3·07	2·77	*2·83*
Sind Sudhar	2·20	2·22	2·33	2·71	*2·37*
289F/K25	2·72	2·61	2·98	2·82	*2·78*
289F/124	2·67	2·52	3·11	2·97	*2·82*
Mean (±0·11)	*2·57*	*2·53*	*2·87*	*2·82*	

Experiment No. 32 — Pad Idan (1946)

Variety	Sowing dates				
	22 May	7 June	22 June	7 July	Mean (±0·05)
M4	2·10	2·16	2·26	2·38	*2·22*
Sind Sudhar	1·24	1·62	1·80	1·99	*1·66*
Mean (±0·11)	*1·67*	*1·89*	*2·03*	*2·18*	

Amelioration of 'bad opening' by application of nitrogen. The effect of the application of nitrogen fertilizers on light sandy lands on the opening of bolls was studied in some of the experiments and it was found that manured plants produced better maturity of seeds than the unmatured plants.

The results of boll weights are given for the experiments conducted at Denisar Estate, Hyderabad and Sakrand in the following Table IV :

TABLE IV

The remedial effect of the application of sulphate of ammonia on 'bad opening' of bolls

—	Experiment No. 4 Denisar Estate (1944)		Experiment No. 18 Hyderabad (1944)		Experiment No. 26 Sakrand (1944)	
	Control	Manured	Control	Manured	Control	Manured
M4	2·42	2·60	3·17	3·26	2·83	3·06
L. S. S.	2·28	2·40	2·55	2·80	2·13	2·49
Sind Sudhar	2·06	2·14	2·52	2·72	2·22	2·65
Mean	*2·25*	*2·38*	*2·75*	*2·93*	*2·40*	*2·73*
S. E.	±0·06		±0·03		±0·06	

There was a significant increase in boll weight as a result of application of sulphate of ammonia indicating better maturity of seeds in the manured plots. It may be mentioned that 'bad opening' was generally more pronounced on soils with saline subsoils than on light sandy lands. As two sowing dates were included in the above experiments the results for the control and manured plots were an average of two sowing dates and consequently the ameliorative effect of later sowing has increased the boll weight in the control plots. If the results of control and manured plots of the first sowing are studies separately, the differences between the boll weights under two treatments would be still greater.

Amelioration of 'bad opening' by frequent irrigations. An experiment to study the effect of frequent irrigations during the fruiting stage on the 'bad opening' of bolls was conducted at Sakrand. The three watering treatments were W1=watering at 20 days' interval ; W2=watering at 15 days' interval and W3=watering at 10 days' interval. Three varieties M4, *Sind Sudher* and 289F/K25 were included in the experiment. The results of boll weights are given in Table V.

TABLE V

Weight of seed cotton per boll in gm.

	Watering at an interval of			Mean (±0·44)
	20 days	15 days	10 days	
M4	3·30	3·08	3·42	3·26
Sind Sudhar	2·89	2·93	3·12	2·98
289F/K25	3·21	3·13	3·66	3·33
Mean	3·14	3·05	3·40	..

Watering at an interval of ten days had significantly increased the boll weight.

Results of all experiments on amelioration of 'bad opening'. The results of the mean weights of seed cotton per boll in gm. under different sowing dates averaged over all other treatments along with standard errors for the 16 complex experiments conducted from 1943 to 1946 are given in the following Table VI. A study of the results will show that there was a progressive increase in the weight of seed cotton per boll as the sowing was done later in each tract of Sind indicating 'better opening' of bolls. In experiment No. 19 conducted at Hyderabad the boll weights under all the four sowing dates were nearly the same indicating normal opening under all sowings.

TABLE VI

Mean weight of seed cotton per boll in gm. under different sowing dates

Experiment number	Place	Year	Sowing dates				S.E.
2	Denisar Estate	1943	2 April	23 April	16 May	3 June	
			2·53	2·77	3·11	3·23	±0·072
3	do.	1944	25 March	15 April	4 May	25 May	
			1·60	1·89	1·05	2·04	±0·68
4	do.	1944		18 April		22 May	
				2·21		2·42	±0·061

Table VI—*contd.*

Mean weight of seed cotton per boll in gm. under different sowing dates

Experiment number	Place	Year	Sowing dates				S.E.
6	Denisar Estate	1946	1 April	15 April	30 April	15 May	
			2·28	2·40	2·51	2·69	±0·068
7	Kinjhejhi	1943	29 March	19 April	8 May	30 May	
			2·14	2·45	2·60	3·14	±0·062
8	do.	1944	8 April	26 April	15 May	3 June	
			2·38	2·64	2·79	2·92	±0·076
12	Mirpurkhas	1943	9 April	30 April	20 May	10 June	
			1·73	2·10	2·90	3·23	±0·074
18	Hyderabad	1944		22 April		22 May	
				2·70		2·98	±0·035
19	do.	1944	17 April	7 May	3 June	24 June	
			2·94	2·85	2·86	2·90	
20	do.	1945		30 April	21 May	11 June	
				2·84	3·04	3·68	
21	do.	1946	15 April	30 April	15 May	30 May	
			2·56	2·67	2·71	2·85	±0·069
24	Sakrand	1943	14 May	3 June	24 June	17 July	
			2·57	2·53	2·87	2·82	±0·11
25	do.	1943	22 May	10 June	3 July	22 July	
			2·85	3·28	3·39	3·26	

TABLE VI—*contd.*

Mean weight of seed cotton per boll in gm. under different sowing dates

Experiment number	Place	Year	Sowing dates				S.E.
26	Sakrand	1944		25 May		25 June	
				2·44		2·69	±0·068
29	do.	1946	18 May	3 June	22 June	8 July	
			2·25	2·45	2·45	3·01	
32	Pad Idan	1946	22 May	7 June	22 June	7 July	
			1·67	1·89	2·03	2·18	±0·11

SUMMARY

Investigations were conducted in Sind to determine the causes of the 'bad opening' of bolls containing immature seeds and weak fibre in the Sind-American cottons and to remedy it by applying the same measures that were successful in remedying *tirak* in the Punjab-American cottons in the Punjab.

The same two soil types (i) soils with saline soils and (ii) light sandy lands deficient in nitrogen were found to be associated with the 'bad opening' of bolls, as was the case in the Punjab. Drooping of leaves on the first soil type and the yellowing and subsequent reddening of leaves on the second soil type were also found to occur.

The application of sulphate of ammonia to light sandy lands and of frequent irrigations to soils with saline sub-soil was found to remedy immaturity of seed and lint. The late sowing was, however, found to be a common remedy for 'bad opening' on both the soil types.

The results of 16 multifactor experiments conducted in different parts of Sind are given to show the ameliorative effect of late sowing on the 'bad opening' of bolls as measured by the boll weight method.

ACKNOWLEDGEMENT

This investigation was undertaken at the suggestion of Sir Roger Thomas, C.I.E., Agricultural Adviser to the Government of Sind. The author has to express his thanks to Rao Sahib B. B. Desai, Deputy Director of Agriculture, Hyderabad, for his valuable help in the conduct of the experiments.

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THE PROSPECTS OF INDIA RUBBER AND PARA RUBBER IN INDIA

By K. Biswas, M.A., D.Sc. (Edin.), F.R.S.E., Superintendent, Royal Botanic Garden, Calcutta

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(With Plates X-XIV and five text-figures)

RUBBER was considered to be one of the most precious articles of commerce in the last global war for obvious reasons. During the latter period of the war, the allied nations felt extreme scarcity of Para rubber because of the fact that the largest rubber producing areas soon came under the occupation of the Japanese.

In 1940 shipments in long tons from the occupied areas and the percentages of world shipments were—Malaya : 540,417 or 38·9 per cent, Indo-China : 64,437 or 4·6 per cent ; Siam : 43,940 or 3·2 per cent ; Sarawak and North Borneo : 52,789 or 3·8 per cent. This loss leaves a gap on the basis of the estimated 1941 import requirements of about 130,000 tons which could be covered without difficulty by greater use of reclaimed rubber and the development of existing synthetic production in the U. S. A.*

With the occupation of Sumatra and the rest of Borneo by the Japanese the rubber position was serious. In 1940 shipments from Sumatra and Borneo accounted for 80 per cent, and from Java for 20 per cent, of the Netherlands East Indies, total production of 536,740 tons. This loss of an additional 38·6 per cent increased the gap to about 670,000 tons or on the basis of the 1941 quotas, to 800,000 tons.*

Conditions deteriorated still more when all the British plantations in South Burma were also occupied by the Japanese. Frantic attempt was, therefore, made by the allied nations to replace the shortage in the supply of rubber for various war purposes. Researches for the production of synthetic rubber were carried on vigorously and all kinds of rubber yielding plants were the subject of investigation. In the Jodrell Laboratory at Kew, the rubber contents of *Taraxacum Kok-Saghys* and in India of *Cryptostigia grandiflora*, an ornamental spreading shrub, imported to India from the tropical Africa, received particular attention. The India rubber tree (*Ficus elastica*) of which there are many a legend about its rubber yielding capacity also formed, like that of *Cryptostigia grandiflora*, subject of careful consideration.

Ficus elastica—*the India rubber tree—its possibilities as a source of rubber*

The writer in full agreement with Mr. I. H. Burkill is not at all hopeful about the prospect of utilizing rubber from these two species on account of the poor quality and yield, with high resin contents of their latex. Nevertheless, much bootless efforts were made in some parts of India towards large scale cultivation and manufacture of rubber from *C. grandiflora*.

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* Amrita Bazar Patrika notes on rubber market (London correspondent of Partika, 1942).

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Attention was also focussed on two plantations of India rubber trees in the Sikkim State. These were started some 50 years ago by some unknown German planter. Most of these trees have reached yielding capacity a few years ago. I have studied these plants both at Mangbar (Plate XI, fig. 3) and higher up at Ranikhola forest blocks along either sides of the Lachen-Gangtok trade route which leads to Tibet across the high mountains of East and North Sikkim. I have also had the opportunity to study the vast rubber plantations and factories in Tennasserim, Mergui District of South Burma consecutively for three years from 1930 to 1932, and discuss various horticultural and economic aspects of the true rubber trees with the experienced planter, Mr. G. A. M. Forbes, of the Mergui Rubber Plantation and Mr. I. A. Ford of Tennasserim Rubber Plantations (Plates X and XI, fig. 2).

Conditions of rubber plantations in South Burma were extremely disappointing at that time when the price fell to 3 annas per lb. and Mr. Forbes once a rubber prince in that part of the world ran short of funds even to keep the plantations in proper order. Nearly all the plantations were then left untapped due to the slump in the rubber market. I have thus been able to form some idea about the prospect of the two rubber yielding plants, *Hevea brasiliensis*, the true Para rubber trees, and *Ficus elastica*, the India rubber trees, which have recently been studied. In the present paper I have briefly recorded my observations on these two rubber yielding plants together with my views on the complicated economic question concerning cultivation and future position of rubber in the world market.

Experimental cultivation of India rubber in India

In the Mangbar block about 66 acres are under *Ficus elastica* plantation Records so far available show that the trees were planted some time between 1902 and 1911. The plantation extends over nearly a couple of miles on either side of the Lachen Road. There were approximately 60 to 80 plants per furlong in the area (Plate XI, fig. 3).

The Ranikhola block forms a much smaller compact patch of several hundreds of trees further higher up the road spreading over more exposed hill sides. These trees are comparatively younger and they were found to be not so much subjected to tapping as those of the Mangbar plants (Plate XIII, fig. 5).

The India rubber tree *Ficus elastica* of the family of *Urticaceae* seems to grow naturally in these forests, sometimes starting life as an epiphyte like *Ficus benghalensis* and *Ficus religiosa*. The trees are very large with rather widely spreading branches and a number of cord like aerial roots hanging downwards from the branches close to the trunk. Thick buttressed roots sometimes extend over the surface of the ground all round the base of the tree. All parts of the tree are covered with brownish grey glabrous bark. Leaves are 6 to 10 inches $\times$ 2 to 3 inches large, coriaceous, shining above, oblong-elliptic with a short petiole and a very prominent thick midrib (fig.1). The trees measure about 40 to 120 ft. in height and about 6 to 15 ft. in girth. Tropical and sub-tropical rain-forest zone is the favourite habitat of the species. Hence this caoutchouc yielding fig tree is seen in abundance in the Terai forest of Sikkim, Assam, Burma and Malaya extending from the base of the Eastern Himalaya to Ceylon, Malaysia and islands in the Far East. The

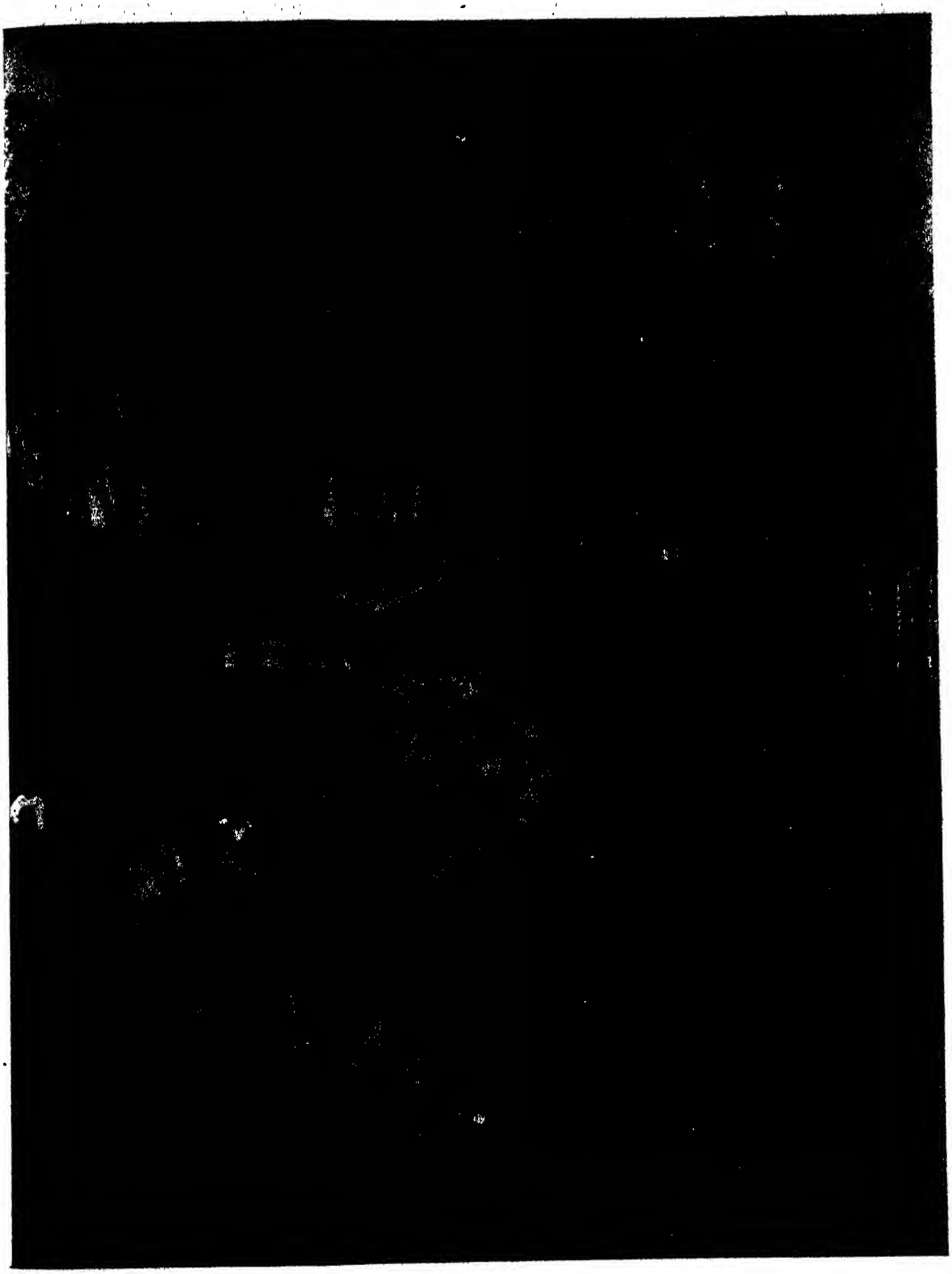

FIG. 1. A portion of the Para rubber plantation in Morgui, South Burma, showing the nature of the bole and branching with a number of Burmese labourers of the plantation. The newly caught elephant with her young one is being domesticated and used for carrying fuel, removing logs and various other works. The writer is seen just behind the calf.

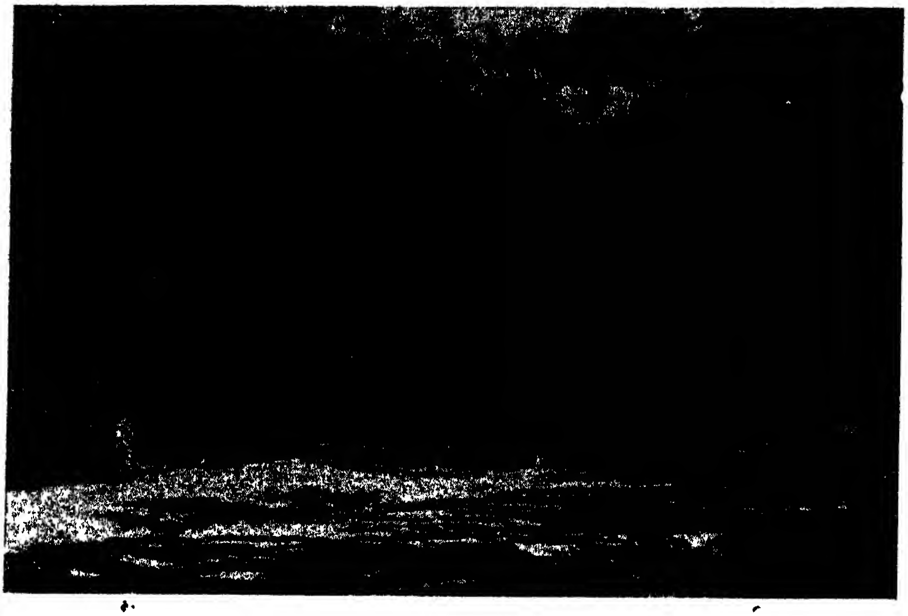

FIG. 2. A general view of the Tennasserim plantation of the *Hevea brasiliensis* showing the spacing of the trees and upkeep of the plantation.

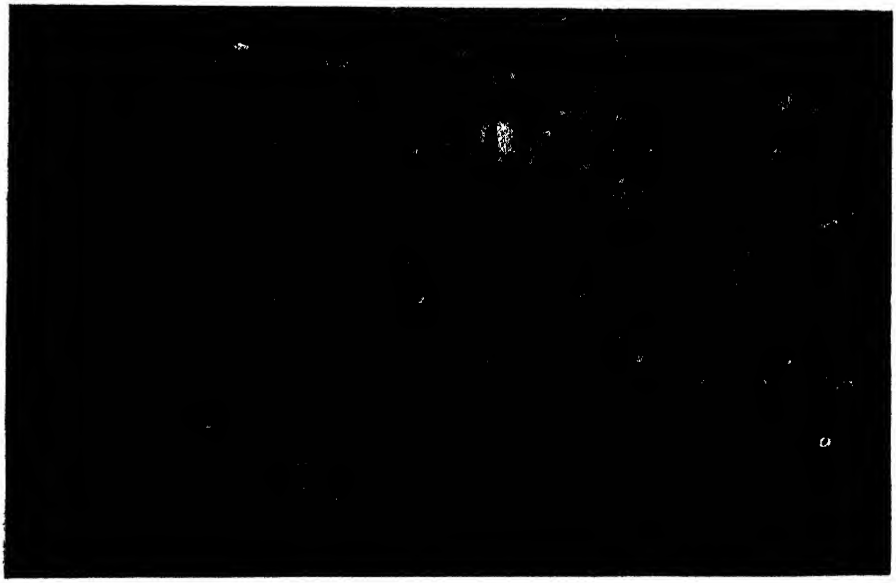

FIG. 3. View of the Mangbar plantation of India rubber trees (*Ficus elastica*) on the Lachen Road to Gangtok, Sikkim, showing the nature of the trunk and branching which indicate how difficult it is to work with these trees.

FIG. 4. Showing the old incisions on the trees when rubber was extracted some years ago and also collection of latex by my Herbarium assistant, Sri Jogendra Nath Naskar from a newly made incision.

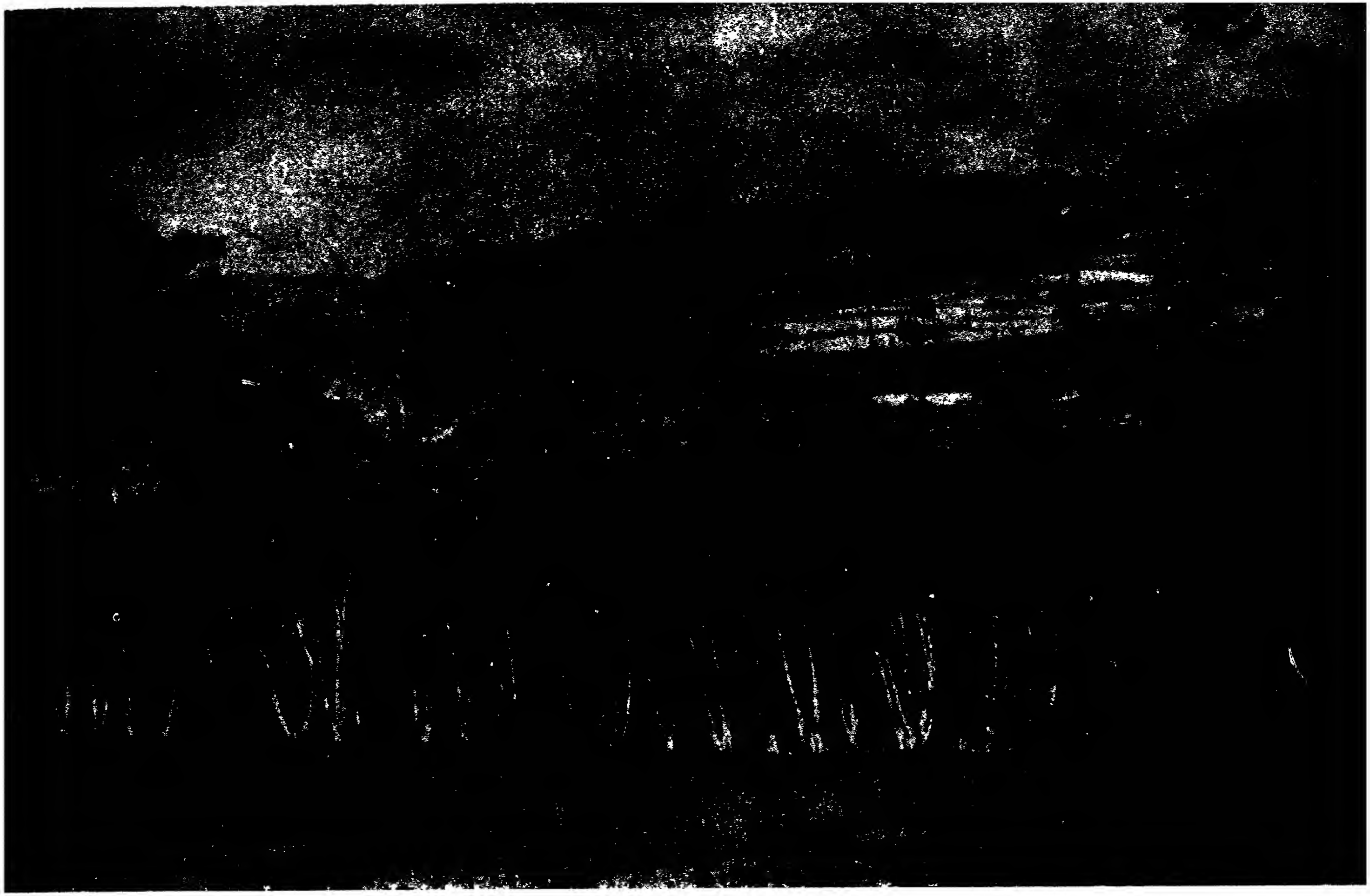

Fig. 5. Portion of India rubber plantation near Ranikhola further higher up on the Lachen Road. In the background is seen terrace cultiv[illegible].

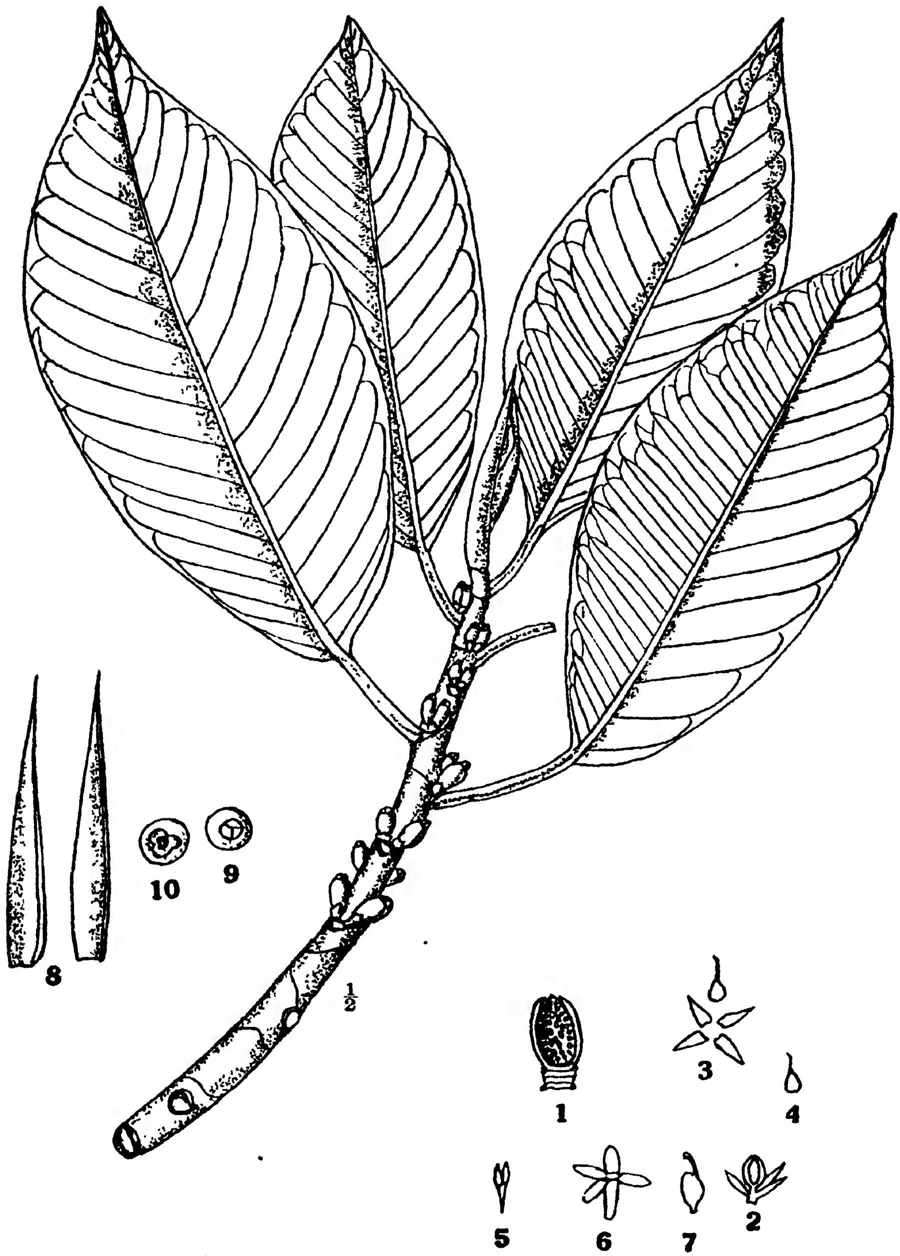

FIG. 1. *Ficus elastica* Roxb. Fruiting branch showing leaves and receptacles.

1. Vertical section of receptacle.
2. A male flower.
4 and 5. Gall flowers.
6. A male flower, the perianth being removed.
7. The same, the perianth being opened out and the anther removed.
8. Stipules.
9 and 10. Apex and base of receptacles respectively.

cultivation of the India rubber trees had, as reported by Brown, been started in 1914, in India at Kulsi and Charduar in Assam and on a smaller scale in Madras and Mysore and also in the Malaya Peninsula, Java and Sumatra. No accurate information, however, is available about the actual date of establishment of these two fairly large plantations. Records indicate that they were started during the early decade of the 20th century along these hill slopes of the Eastern Himalaya between an elevation of 1,000 ft. and 2,000 ft.

Cultivation.—The cultivation of the Indian fig rubber tree is very simple as it can easily be propagated from seeds, cuttings and layerings. It is advisable to raise the plants from seeds after treating them with the usual methods in the nursery. The seeds may be sown in boxes containing three parts of good soil and one part of leaf mould. The seeds germinate within five to fifteen days according to their viability and climatic and edaphic conditions. The seedlings when four to six inches high may be transferred to a protected, shady, well drained nursery bed and placed at a distance of one to two feet apart. When these are about three to six feet high, they may be planted in the open at a distance of 30 ft. apart and when sufficiently tall they may be thinned out and subsequently the plants may be allowed to grow 60 ft. apart. The fig rubber tree is a surface feeder hence in Assam they are sometimes planted, when 10 to 15 ft. tall, on a mound preferably on ant hills where the growth is faster than in the plain wasteland. In Assam, plantation records show that the tree grows to an average height of 22·5 ft. and average girth of 1·39 ft. in five years, and 85·0 ft. and 23·16 ft. in 24 years. The average annual rate of growth during 24 years of trees after planting in the open at Charduar, Assam, was about 3·38 ft. in height and 0·99 ft. in girth. Table I illustrates yield of rubber in Assam plantation.

TABLE I

Yield of rubber in Assam plantation

	Area tapped in Acres	Number of trees tapped	Yield of rubber		
			Total lb.	Per tree lb.	Per acre lb
Charduar—					
1907-8	642	8,265	8,346	1	13
1908-9	417	4,734	7,560	1·6	18·1
1909-10	348	5,542	12,971	2·3	37·3
1910-11	336	4,327	9,087	2·1	27·0
Kulsi—					
1907-8	88	2,087	4,083	2	46
1908-9	66	3,955	2,573	0·65	39
1909-10	88	1,477	3,240	2·2	36·8
1910-11	66	..	..	0·9	52

'The trees at Kulsi are planted much closer than those at Charduar, and hence the yields per acre are higher.

In Cachar a number of trees tapped by making numerous small cuts with a chisel, gave the following results.

Eight trees planted in 1882 were tapped in 1905-6 and gave an average yield of 6 lb. of rubber per tree. The same trees tapped in 1906-7 gave an average of 5 lb. per tree, the individual yields varying from $2\frac{1}{2}$ lb. to 10 lb.

Four younger trees, planted in 1889-90, gave an average of about 2 lb. of rubber in 1905-6 and $2\frac{1}{4}$ lb. in 1906-7, the individual yields in the latter year being $1\frac{1}{4}$, $2\frac{1}{4}$, $2\frac{1}{2}$ and $3\frac{1}{2}$ lb. [Brown, 1914].

Coagulation of the latex of India rubber is variable and it coagulates quickly on exposure to light. The rubber is obtained often as scrap. Burgess recommnmends the use of tannic acid as the best coagulant for *Ficus elastica* latex, and has proposed the following process. The latex, which should not be diluted with water, is warmed to 40° C., and a solution of tannic acid of known strength is then added until there is 1 per cent of tannic acid in the latex. Thus using a 20 per cent solution of tannic acid, one part of the solution would be added to nineteen parts of the latex. The latex is then gently churned, avoiding violent agitation, and in one or two minutes it sets to a cream and complete coagulation occurs' [Brown, 1914].

The following extracts from Burkill's *Dictionary of Economic Products of the Malaya Peninsula* on *Ficus elastica* as a rubber yielding plant in addition to my account of the India rubber tree supply a more less complete information on the cultivation and possibilities of this rubber yielding tree in India and the East.

> 'It has undergone a long trial in experimental cultivation as a source of rubber but has quite lost its place before *Hevea brasiliensis*, though a little rubber, is still got from it in Assam and Burma.
>
> 'The chief reason why it has lost its place is that there is a resin about 4 to 20 per cent, in the rubber, which hardening in course of time, annuls the elasticity.
>
> 'The leaves contain slime, which is not elastic (*Tropenpflanzer*, 1900, **4**, 230).
>
> 'Rubber from this fig appears to have been used in North-Eastern India for lining receptacles long before Europeans know anything about it. In 1810 Roxburgh received in Calcutta, from Assam, some honey in a rattan receptacle lined with it, and recognized that the material was like the caoutchouc of South America, which by then, from the custom of erasing pencil marks with it, had got the name of India rubber. Some years later a French miner working in Upper Burma, found it in use for lining baskets used for baling water.
>
> 'Knowledge that it could be obtained in Assam gradually spread ; soon after 1830 it entered into the export trade of Calcutta, and remained in demand foı a short time ; but the trade gradually declined.
>
> 'When a Forest Department was formed in India, the India rubber from fig immediately came under study as a possible source of revenue. Its rubber appeared also in the markets of Java, Sumatra and Indo-China ; and a like

product in Malaya as well, the source of which was not discovered by Collins (*Rep. on Caoutchouc*, 1872, 22), but was made evident by Murton as *F. elastica* (*J. Roy. As. Soc. Straits Branch*, **1**, 1878, 107).

Under the Indian Forest Department in North-Eastern India and contemporaneously in Java, planting was done. Very tardily Malaya followed suit' [Burkil, 1935].

The interest reached its peak in 1900 when simultáneous planting of Para rubber trees also started and soon after from 1906 to 1909 the interest was disappearing and in 1911 the cultivation of Para rubber in the east was abundant.

The India rubber fig may be tapped by incisions with a rest of about three months between each tapping. There is little in the method at all comparable with the method of tapping *Hevea* for rubber, and as a rubber-yielder the fig is far behind.

The age of the tree probably determines the amount of resin, old trees carrying less than young ones. Tapping begins at the age of five years. The yield is set down as increasing from 20 grammes of rubber per annum per tree to 250 grammes in the tenth year, and 1800 grammes in the eighteenth. In order to make room for growth the trees, originally rather thickly planted, have to be thinned to one-quarter, so the rate of increase per acre is far from being correspondingly rapid [Preuss in *Tropen-pflanzer*, **23**, 1920, 173]. One very old tree is said to have given at its first tapping 3 pikuls, or over 3½ cwt. of rubber [Reintgen in *Beihefte 2/3 zum Tropenpflanzer*, **6**, 1905, 197].

The latex is found chiefly in the inner bark, close to the cambium. The bark at this place is so constructed that on attempting to cut it with a tapping knife, it tears, being unequally firm ; this makes tapping as done with *Hevea* almost impossible. Instead, the bark is slashed or incised, and the latex allowed to coagulate, or to drop on to leaves spread below to catch it. The porduce is then like scrap rubber. The tapping may be done by incisions arranged in a hering—bone pattern for the convenience of getting the drops of latex to run together ; but the injury remains proportional to the number and length of the cuts, though these heal readily.

The latex in bulk coagulates uncertainly. The result of this was that all the earlier 'rambong' collected came into the market as scrap. But when, about 1908 processes were devised for treating latex in various ways, with ammonia or tannin, a biscuit form appeared, as well as sheets and cakes. But by this time interest in it was disappearing [Burkill, 1935].

It is learnt that the trees of the Mangbar block were tapped, for the only time in the year 1943-44 and 408 lb. of rubber collected and sold to Messrs. Bata Shoe Company, Batanagar.

'V' shaped scars of incision were observed all over the trunks and thick lateral branches of many large trees. Some of the main stems, large branches and buttressed roots were tapped too. The latex from all parts of the trees comes out almost immediately after the incision is made.

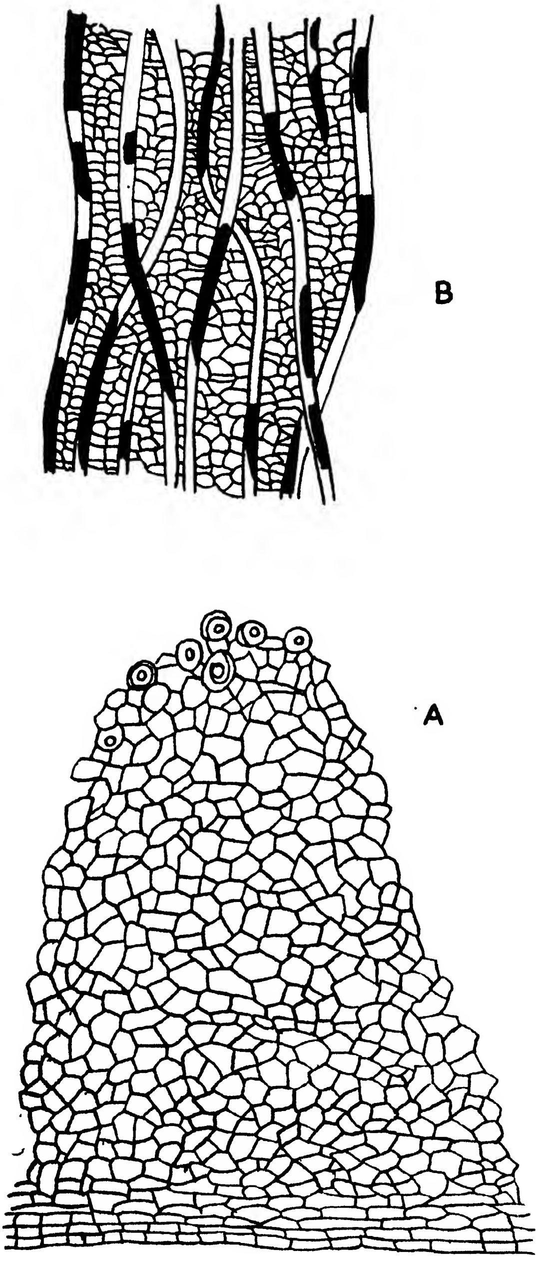

FIG. 2, A. Transverse section of bark of *Ficus elastica* (India rubber tree) showing the patches of laticiferous tubes filed with caoutchouc rubber (r).

FIG. 2, B. Longitudinal section of the bark of *Ficus elastica* (India rubber tree) showing the long laticiferous tubes blocked by patches of caoutchouc (r).

The bulk of the milk is collected from the main trunk and thick stout branches. Samples of latex were gathered from the trees growing in shade as well as in open sun light.

It was observed that the flow of latex was quicker in the plants growing in shade than those exposed to direct sun light. The rate of flow was about 1 oz., in 5 minutes. The optimum rate of flow of latex in the trees under the shade was found to vary between 15 seconds to 2 minutes after the incision was made. The rate of flow was found to be gradually reduced and after 10 minutes only a few drops came out at an interval of about five seconds and then the latex in the cut area began to coagulate. But in the plants growing in direct light, the latex coagulated within five minutes after the incision was made. The trees tapped are full grown trees about 40-45 years old (Plate XII, fig. 4).

In the transverse section of the bark of an adult tree of *Ficus elastica*, it was found that the laticiferous tubes were situated rather deeper on the inner side adjacent to the cambium layer and on the outer side below a layer of some 50 cells from the surface layer of the cork cells. The laticiferous tub ecan easily be distinguished from the other cells by the presence of coagulated rather pale brown rubber in them. In a longitudinal section laticiferous vessels were seen to form a richly anastomosing system extending below the surface layer of the cok throughout the entire length of the stem and the mature branches.

The laticiferous vessels are all fully developed and the maximum diameter of a tube is about 28 μ and the minimum about 16 μ (Fig. 2, A and B).

The chemical examination of the latex from India fig rubber trees of Mangbar block was carried out about two weeks after it was collected from the tree. It coagulated very rapidly after collection. It had a slight pinkish colour and a faint ethereal smell.

The results of the chemical analysis of the latex of India tubber trees are shown in the Table II.*

TABLE II

Results of the chemical analysis of the latex of India rubber

Rubber	Moisture	Total solid	Ash	Resin	Hydro-carbon	Total insoluble matter	Acid value	Nitrogen and protein
per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent.
60·78	19·21	80·79	2·555	8·824	824·45	89·12	38·64	0·5572

* Chemical analysis was carried out by Sri Promode Banerjee, M.Sc., Chemist under Rose Cultivation Scheme started under auspices of Council of Scientific and Industrial Research.

Comparison of some of the properties of *Ficus elastica* latex with those of *Hevea brasiliensis* latex is given below :

——	*Ficus elastica* per cent	*Hevea brasiliensis* per cent
Resin content	8·824	1·3
Nitrogen content	0·08915	0·4
Protein content	0·5572	2·5

The properties compare more favourably in the case of Assam and Madras plants as recorded by Brown and given in the Table III.

TABLE III

Comparison of Assam and Madras plants

Country	Description of rubber	Caoutchouc per cent	Resin per cent	Protein per cent	Insoluble matter per cent	Ash per cent
Assam—						
Charduar	Tree rubber	77·5	19·3	1·5	1·7	0·5
Kulsi	do	78·6	19·1	0·9	1·4	0.5
do	Mat rubber	81·9	16·2	..	1·9	1·9
Madras—						
Mukkie	Scrap	67·9	28·4	0·9	2·8	0·5
do	Biscuit	74·3	23·6	1·0	1·1	1·7
Madras—						
Parlakimedi	Cake	88·6	8·1	1·4	1·9	0·5

Conclusion

From the physical properties studied and the chemical data of the latex it is clear that it does not favourably compare with the Para rubber (*Hevea brasiliensis*). It may, however, be used when mixed up with Para rubber for the preparation of soles and heels of shoes and other articles in which block rubber is used.

Hevea Brasiliensis MUELL. ARG. (Para rubber tree)

History

The first systematic study of the South American rubber plants was made by Charles Marie de La Condamine as early as 1735 and in the year 1736, he handed over the specimens of rubber to the French Academy of Science stating that the product was obtained from a tree called '*Hevea*' by the natives in Ecuador [Brown, 1914].

But no further information about the botany of *Hevea* was obtained until 1865 when the genus was studied and described for the first time by J. Mueller and the tree which yields the famous Para rubber was named *Hevea brasiliensis* Muell. Arg. by him [Brown, 1914].

Previous to 1860 Para rubber was exported only in small quantities and it was not until 1876 when this rubber plant was introduced into Ceylon and Malaya from Sir Henry Wichham's collection of seeds from Rio Tapajo [Wright, 1905]. The first introduction of Para rubber in Mergui (Burma)was made in 1877 and in 1878 it was introduced into Madras [Wright, 1905].

First export of this rubber was made from Ceylon in the year 1884 [Wright, 1905] and from Malaya in 1899 [Burkill, 1935]. Definite records are available with regard to the collection of Para rubber in India and South Burma where, (Plate XIV, fig. 6) the trees have fully established and rubber was extracted uptil the year 1930. The 74 years old tree which was introduced to the Royal Botanic Garden in 1873 is still in perfect health in the Royal Botanic Garden, Calcutta. There is hardly any difference in growth and latex contents between this tree of lower Bengal and the tree of rubber plantation in Mergui, South Burma. The following extract gives the early history of introduction of Para rubber tree (*Hevea brasiliensis*) into India, Ceylon and Burma.

Bengal. 'It has been ascertained from the Superintendent of the Royal Botanic Garden, Calcutta, that nearly ten years ago a quantity of the seeds of this tree (one of the species from which South American India-rubber is obtained) was sent to the Royal Botanic Garden, Calcutta from Kew. Some of these seeds germinated, but it was found that the resulting seedlings were extremely sensitive to cold, and that the low temperature of the cold weather of Bengal proved fatal to them, even when planted in the most sheltered situations. Some of the seedlings were supplied to tea planters likely to give attention to their culture, and some were sent to Mr. Mann, the Conservator of Forests in Assam. The results obtained by these gentlemen were, however, the same as those obtained by Dr King and it was on his recommendation that subsequent supplies of *Hevea* seeds were sent to Ceylon, instead of to India. The Superintendent thinks that *Hevea* will grow well in Provinces like Malabar or Lower Burma, where the climate is said to be moist and equable, but in Northern India, where there is a distinct cold season, Dr King is of the opinion that cultivation is not likely to prove successful.

Fig. 6. The trunk of the *Hevea brasiliensis* in Tenasserim showing the newly made incisions at the base of the tree with the Ceylonese Officer and his Burmese wife and children. In the background is his bungalow mostly made of bamboo and cane.

'The Conservator of Forests, Bengal, who has also been consulted on the subject, reports that it does not appear that any experiment in the culture of the tree in question has ever been undertaken by the Forest Department in this Province'.

Burma. Colonel W. J. Seaton wrote of Tenasserim : 'Early experiments—Experiments on a small scale were commenced at Mergui in 1877, with eight seedlings, the survivors of a small batch received from Dr King, of the Botanical Gardens, Calcutta. They were successfully set out in the Forest office compound at Mergui, and although on a low hill, a not very desirable site, yet their growth was for some time satisfactory. In 1879, a large number of *Hevea* plants believed to be well rooted cuttings, were forwarded by Dr Thwaites, of the Royal Botanical Gardens, Ceylon and although in the charge of a subordinate who had been sent to Ceylon for special instructions, only 178 survived the voyage. These were set on low ground drained by the sources of the Boke Chaung, a small tidal creek. Only 61 of the healthiest plants survived the planting operation, and of these again casualties continued to take place yearly, owing chiefly to attacks of white ants until the number was reduced to 50 in 1886, since when there have been no further casualties' [Watt. 1890].

Description. A large tree attaining a height of 60 to 100 feet and a girth of 8 to 12 feet, leaves trifoliate with long petiole (3-4 in. long) ; leaflets 4 to 6 inches by $1\frac{1}{2}$ to $2\frac{1}{2}$ inches, ovate lanceolate, tapering at both ends. Flowers unisexual, small, green, in long panicles of variable length. Fruit a three celled triangular capsule each cell containing one oval seed with shiny testa (fig. 3). Flowering in cool season of January and fruiting in March and April. The fruits ripen in the rainy season in July and August.

Distribution. A native of South America and widely distributed in the Amazon and Orinoco river valleys introduced into all the tropical countries chiefly in India, Ceylon, Malaya, Java and Sumatra.

The following extract from Sir D. Brandis' review of Mr. Collins' report gives the tracts of India which Sir D. Brandis anticipated, and which all subsequent experience since 1873 has confirmed, as being most suited to Para rubber. Having compared the extremes of climate and also the means, on the west coast of India and Burma, with that of Brazil, he remarks : 'We may, therefore, conclude that Kanara, Malabar, Travancore, and the Burma coast, from Moulmein southwards, offer the desired conditions as regards temperature, for the successful cultivation of the caoutchouc-yielding species of *Hevea.* I would specially draw the attention of Forest officers in this respect to the moist, evergreen forests at the foot of the Coorg Ghats, and in Kanara, as well as to the Attaran valley and similar localities in Tennasserim' [Watt, 1890]. In fact large scale planting of *Hevea brasiliensis* as shade tree was successfully done in chinchona plantations of Tenasserim, Mergui, South Burma under the then Government of India during 1920 to 1930.

The climatic and edaphic factors prevailing in several parts of India indicate possibilities of large scale cultivation of Para rubber in India and in the hot and humid hilly regions particularly in the Chittagong Hill tracts, now Eastern Pakistan,

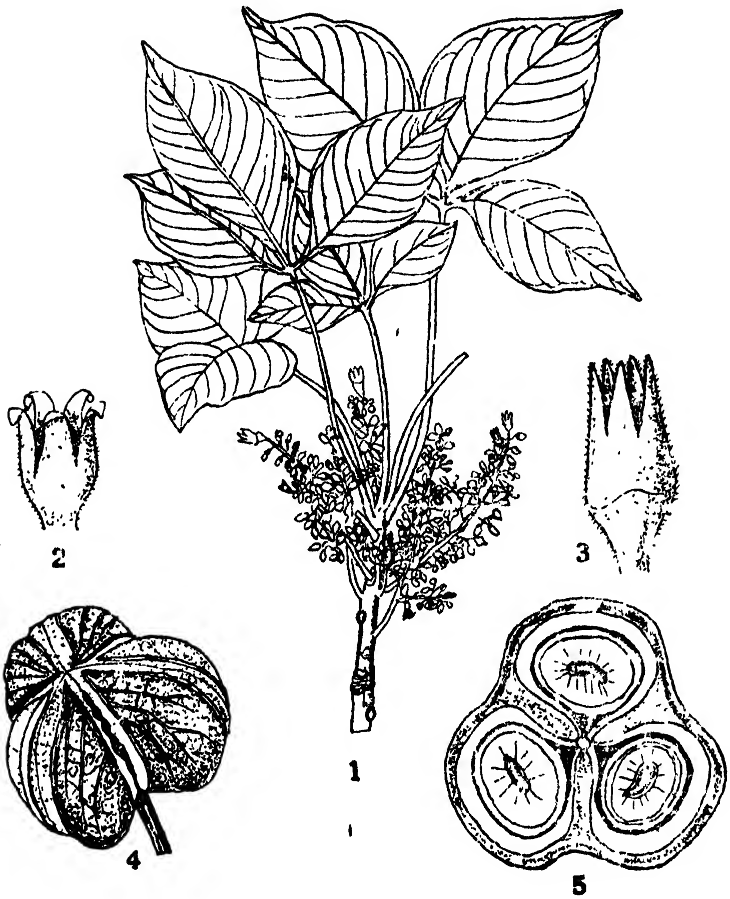

FIG 3. *Hevea brasiliensis* Muell. Arg.

1. A twig showing leaves and inflorescence
2. A female flower
3. A male flower
4. A fruit
5. Cross section of the fruit showing the seeds

Tripura in Bengal and across Manipur, Assam towards the north-east, and southwards to South Burma along Arakan Peninsula down to Tennasserim and Victoria Point in the south east, in addition to the present areas in Southern India and Ceylon which are now under cultivation of *Hevea brasiliensis.* The low hills of the Ganjam District, the lower seaside slopes of the Eastern and Western Ghats (REPORTED BY E. B. C. MODDER IN HIS No. 1414, as recorded in his herbarium specimens) and some of the suitable areas in the Duars and the Terai regions of the Eastern Himalayas may also be under experimental plantation with a view to meeting India's internal consumption of this valuable article required for various important industries. It is also expected that our leading scientists will be able to put a plant for the manufacture of synthetic rubber as well, and thereby supplement our total requirement of rubber in our country. The areas under cultivation of Para rubber and India rubber and possible areas for experimental cultivation of Para rubber are shown in a map of India (Fig. 4).

Cultivation of *Hevea brasiliensis*

I. *Climatic conditions. Hevea brasiliensis* can be successfully cultivated in those areas where there is a uniform and moderate temperature and sufficient rainfall throughout the year. The climatic conditions favourable to the cultivation of Para rubber are those as are prevalent in the Tropical Rain Forest areas.

II. *Soil.* For the best and quick growth of the trees, they should be planted in good alluvial soil wherever possible. The trees can also grow in swampy soil provided there is a thorough drainage system.

III. *Formation of plantation.* For the purpose of clearing the land the existing trees should be cut down and the timbers either disposed of or burnt as convenient be ; it is also advisable to remove the stumps of the trees from the soil in order to avoid the attacks of white ants and fungal infection on the rubber trees.

After the clearing of the land, roads and proper drainage are made and the entire plot is divided into blocks. Then holes of 2 ft. square and 1½ ft. deep are made for the reception of the rubber plants.

The Para trees are usually planted at intervals of 15 ft. by 20 ft. (about 150 trees per acre), 24 ft. by 22 ft. (about 150 trees per acre) or 20 ft. by 20 ft. (about 110 trees per acre). According to some, still wide planting (40 or 50 trees per acre) can bring about better results quickly than closely planted trees thereby attaining the required size for tapping more rapidly.

Raising of plants. The Para trees are generally propagated from seeds collected from eight to ten years old trees having a good yield. The plants are usually raised in nursery beds or in seed baskets and rarely seeds are planted 'at stake,' that is, in the position which the trees will occupy.

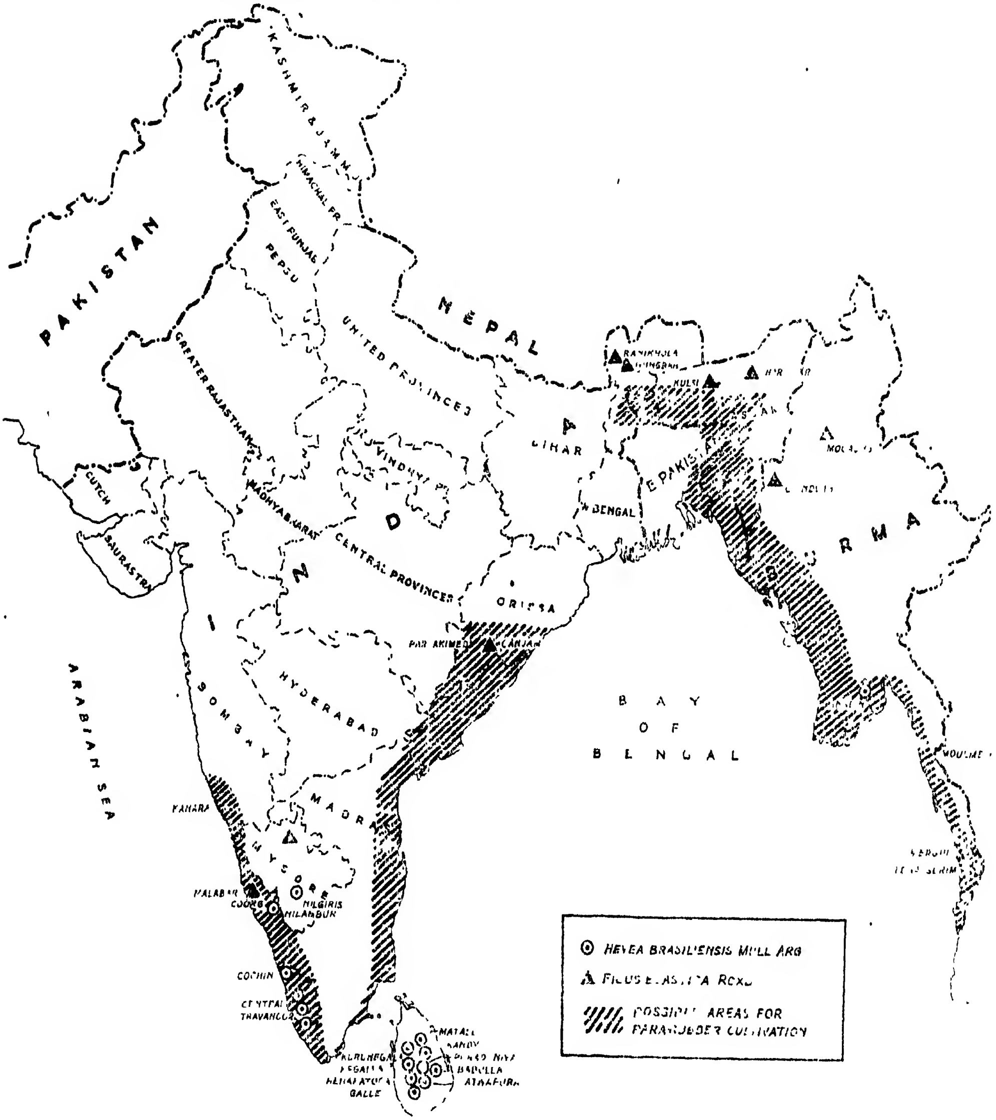

FIG. 4. Map showing the distribution and possible areas of cultivation of India rubber and Para rubber in India and her borders

The seeds are planted in rich soil in the nursery bed six to nine inches apart and one inch below the surface. The soil should be kept moist and the seedlings should be given proper shading against direct sunlight.

The seedlings are transplanted in the prepared holes when they are 2 ft. or 6 ft. high. In the latter case plants are lifted from the beds and after training the roots, these 'stumps' are carried in bundles and then placed in the holes.

The seed basket method for raising the seedlings is highly recommended. Here the entire basket containing the seedling is placed in the hole without disturbing the plant.

As a rule transplanting should be done during rainy weather wherever possible.

Two or three seeds are planted simultaneously in the prepared holes in the case of 'at stake' method of planting. When the seedlings have grown sufficiently the most healthy and vigorous in each hole is retained and the others are removed.

In places where there is a prolonged dry season, it is advisable to provide shade trees at least for the first two years [Brown, 1914].

'The trees grow rapidly, attaining some thirty feet in three years; it is readily propagated by cuttings. Mr. Cross recommends plantations to be made in seasons of inundation or flood, the cuttings being forced into the mud for half their length, leaving enough above ground to save the tops from being actually submerged. Propagation by seed is not so successful' [Watt, 1890].

Anatomy of Para rubber. In a native stem of *Hevea brasiliensis* the following tissues can be traced proceeding from the centre outwards—the pith, the wood, the cambium, the bast, the cortex and the bark. Only the cortex contains the latex tubes. The cortex is about 5-6 mm. thick in 20 to 30 years old trees and in Singapore, Peradeniya trees the thickness reaches upto 9·5 mm. In a cortex 5 mm. thick the latex tubes occur chiefly in the inner 2 mm., the middle contains a few tubes and the outer 2 mm. practically have no tubes.

The laticiferous vessels are formed from rows of special cells arranged longitudinally which can be distinguished from the neighbouring cells by their greater length and by their contents which are generally brownish due to some colouring matter present in the tissues. The transverse walls of these cells undergo absorption forming long, continuous tube or vessel and also the adjacent vessels communicate with one another by lateral passages forming a net work of articulated laticiferous tissue [Petch, 1911].

The latex generally runs for about half an hour after the cut has been made but in some cases it runs for one to three hours.

The trees may reach an age of 200 years but they are generally tapped up to an average of 30 years.

Yield. It has been reported that four to six years old trees with a minimum girth of 20 inches yield 1 to 3 lb. of rubber per tree each year, seven to nine years old trees 7 to 8 lb. and well developed trees above 11 years old give as much as 12 to 35 lb. of rubber per year per tree [Wright, 1905].

Chemistry. In the cultivated Para rubber of the East there is very little moisture or ash and the percentage of resin and protein is also low. The rubber contains 90 to 96 per cent of caoutchouc. The chemical composition of rubber of *Hevea brasiliensis* is very little affected by the age of the trees though it slightly differs in the trees growing under different ecological conditions. The analyses of rubber by Bamber from Para trees growing in Ceylon is quoted below [Brown, 1914].

TABLE IV

Age of the trees and composition of rubber

	2 years	4 years	6 years	8 years	10-12 years	30 years
Moisture	0·70	0·65	0·55	0·85	0·20	0·50
Caoutchouc	91·20	94·58	94·79	94·60	94·35	93·24
Resin	3·60	2·72	2·75	2·66	2·26	2·32
Protein	4·00	1·75	1·51	1·75	2·97	3·69
Ash	0·50	0·30	0·40	0·14	0·22	0·25

Though it is clear from Table IV that Para rubber obtained from young trees might have more or less the same chemical composition as that from the older trees yet the rubber from the young trees is generally deficient in physical properties as it is soft and weak. Thus it can be concluded that very young trees should not be tapped.

Tapping. The Para rubber trees are considered to be ready for tapping when they obtain a circumference of 18-20 in., at a height of 3 ft. from the ground which generally occurs in a tree 4 to 7 years old.

As the thickness of the cortex varies from 1/8 to 1/2 in. according to the size of the trees, the cut should be sufficiently deep to get maximum flow of the latex because the maximum number of laticiferous tissue is situated in the innermost layer of cortex.

The tapping is generally done at the basal portion of the trunk up to a height of about six feet.

The maximum flow of intex is obtained in early morning or late in the evening when the transpiration rate is low.

The frequency of tapping varies considerably. Thus in Celyon tapping every day in alternate months or every day during rainy season or on alternate days throughout the year showed satisactory results.

It may be remarked in this connection that the yield of latex is very small when the Para rubber tree is first tapped or after a long interval but the yield increases to a great extent in subsequent tappings. The characteristic phenomenon has been termed ' wound response ' because the subsequent incisions on the bark acts as a stimulus for the production of latex [Brown, 1914].

The most generally adopted method of tapping Para rubber trees particularly in Ceylon, South Burma (Fig. 5, VI) and Malaya is the half herring—bone system and the incision is restricted to one quarter of the circumference of the tree. A quarter of the stem tapped in this way is continued for a year. The opposite quarter of the stem is tapped during the second year and then the two opposite remaining quarters in the same way in third and fourth year respectively. In the fifth year the renewed bark on the first quarter is tapped and so on.

There are also other methods of tapping *Hevea brasiliensis* trees as follows :

(A) The double herring—bone system, (B) Full spiral and half spiral incisions, (C) ' V ' incisions, (D) 'Y ' incisions for tapping young trees at the base and (E), Vertical incisions.

But the half herring—bone system is the most advantageous method for the following reasons :

(i) It can be employed in small as in large trees but the double herring—bone system can be employed only in big trees.

(ii) It is not harmful even for young trees but the spiral method is harmful, to plants if used continually.

(iii) In this method only one pot is required at the base of the plant thereby saving a large amount of labour as well as the cost of pots.

(iv) Finally, in this method only a quarter of the stem is involved but the other quarters get a sufficient resting period thereby increasing the yield and longevity of the trees.

Sketches of the different methods are shown in (Fig. 5, I to V) after Harold Brown to whom the writer is deeply indebted for obtaining much information from his book on rubber [Brown, 1914].

It will thus be seen that *Ficus elastica* had undergone a fair trial in experimental cultivation in India as a source of rubber. The yield of rubber per tree and per acre is extremely low and its market value is also very poor in comparison with Para rubber obtained from *Hevea brasiliensis.* (1) The chief reason for its low market value is the presence of a resin about 4 to 20 per cent in the rubber (8·824 per cent in the sample examined) which, hardening in the course of time, annuls the elasticity [Brown, 1914]. (2) The yield is very poor in comparison with the true rubber yielding tree—*Hevea brasiliensis.* (3) The trees do not become productive of yielding latex (from the point of view of commercial rate) until a little advanced in age. (4) If the portion where the incision is made, is exposed to light, the latex coagulates very soon and after half an hour it hardens into gelatinous brownish

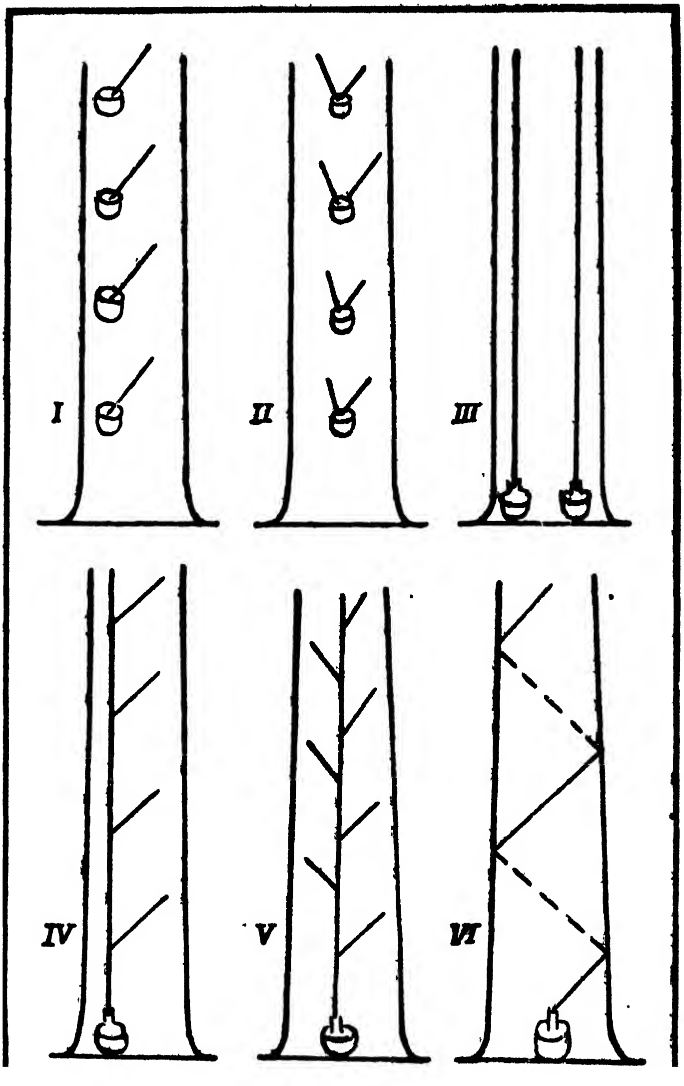

FIG. 5, showing the different tapping systems of *Hevea brasiliensis* (para rubber).

(I) Single oblique incision, (II) ' V ' incisions, (III) long vertical incision, (IV) single herring—bone incision, (V) double herring—bone incision, (VI) spiral incision.

rubber of a brittle nature unlike the milky latex in *Hevea brasiliensis* in which the milk remains liquid for hours after the incision is made. (5) It is difficult to climb over the India rubber trees and collect the latex from all over the low trunks and many branches which are cut on the dorsal side. It is thus not so easy to work with as the true rubber yielding Brazalian tree *Hevea brasiliensis* of the family of *Euphorbiaceae* with its trunk continuously cut in herring-- bone fashion and latex is collected in small cups day by day. This milky latex is then placed into enamel buckets and transferred in the vats to be treated chemically and finally spread into sheets and smoked for various marketing purposes. (6) Vast area of land is required for a plantation of India rubber trees. This is not possible to afford in these days of scarcity of food and shelter.

My study of rubber plantation of South Burma and discussions with some of the experts and owners of the plantation and firms have led me to draw the same conclusion as recently found expressions in some of the latest publications dealing with question of rubber production in different parts of the world.

RUBBER MARKET

The rubber industry is a delicate and highly complicated world problem to deal with. The solution mainly rests on the balance between demand and supply which seems to be the deciding factor, particularly in an age when synthetic rubber is playing by no means an inferior role than the natural rubber in the marketing of rubber as a whole. The rubber problem is also intimately connected with the economic problem of the labour employed in the cultivation and manufacture of rubber. It varies with as my experience shows in the South Burma, the rise and fall in the price of rice, the staple food for most of the labourers employed in the plantations. Moreover, the quality of rubber plays also an important part in modern industry and the last but not least there exists the time factor in raising a new and re-establishing a damaged plantation. If we take into account the yield from the vast tracts of land now under true natural rubber in rubber yielding areas of the world, and consider carefully the position of synthetic rubber in the world market, it will be clear that such rubber yielding trees as *Ficus elastica*, *Cryptostegia grandiflora* and a few other rubber yielding species will be of negligible value in the present as well as future market even in the event of, God forbid, another global war. It is therefore advisable to concentrate on the production of natural Para rubber in the existing plantations and synthetic rubber, which is particularly suitable for some industrial purposes, and at the same time to maintain a balance between supply and demand.

The Sikkim and Assam plantations of India rubber fig trees are therefore of very little commercial value, but the trees serve the purpose of forming a beautiful avenue with canopy overhead along the Lachen Road for a distance of over two miles. The Spaniards also used them in early times in the Philippines as shade trees along the roadside. Some of them are magnificient specimens and may serve as a source of scrap rubber of inferior quality for the purpose of home industry in emergent condition if necessary. They are also of much interest and admiration to the botanists, the foresters and the travellers to Sikkim and Assam.

Before the global war 'each worker tapped about 350 trees (Para rubber trees) a day to produce about thirty-eight pounds of latex. Over the years the handling of rubber was constantly improved by the planters'. Coagulated in porcelain and aluminium lined tanks by acetic and formic acid, the rubber was then dried and pressed into ribbed smoked sheets (Plate XIV, fig. 7). When baled, it was shipped to the rest of the world chiefly in British, Dutch, and the U. S. A. bottoms. The proportion of rubber shipped in the form of concentrated liquid latex rose rapidly just before the war, and this development will continue now that peace has returned to the East. Another basic technical improvement in natural rubber production is bud grafting. In some cases it has raised the yield from 400 pounds an acre to 1,200 pounds. To-day, some estates are looking forward to yields of as much as 2,000 pounds an acre from bud-grafted trees that deserve to be called the 'synthetics' of the botanical world. 'Moreover, there is the increasing production of synthetic rubber and the total rubber capacity of the world has been rightly estimated at nearly three million long tons.'

Against this background of the world production of both natural and synthetic rubber there will be an enormous supply of rubber to meet the needs of increasing postwar industrial purposes. The question of utilising inferior rubber from Indian rubber plants will not therefore arise for years to come and it is doubtful whether it will arise at all on account of improved cultivation of Para rubber trees and production of synthetic rubber in large quantities.

From 1925 onwards productive capacity of natural rubber gradually increased and reached its climax in 1941. Then came the Stevenson's control plan in 1922-1928 and consequent control of production in the British gardens with a view to maintaining high price. It is true that this rubber control price brought a high price, but soon after it resulted in over supply on account of supply coming to the market from the uncontrolled gardens. The over supply led to the glut as a result of which the price came down as low as 3 to 4 annas per lb. in 1929 to 1931 as I myself found in the plantations during my botanical expeditions in South Burma along the border of Siam.

The present rubber market, however, indicates a good profit as the selling prices of 22½ cents per lb. for the natural rubber and 18½ cents per lb. for synthetic rubber, are adjusted to the prospects of postwar industries of the world for some time to come. But when again all the centres of natural rubber are exploited in full swing, taking into account the large rubber of untapped trees in the plantations of the world, many of which have not been properly worked during the war years, and the introduction of improved and latest scientific methods for the supply of natural rubber supplemented by synthetic rubber, the production will be sufficient to meet the increased demands. It is expected that plantations in Malaya, North East Indies and Ceylon will have a productive capacity of 100,000 long tons annually and plantations in India, Burma, Siam, Sarawak and North Borneo will have pro-

ductive capacity of 10,000 long tons per year. Moreover, this productive capacity will be supplemented by 700,000 tons of synthetic rubber. This supply of both natural rubber and synthetic rubber was estimated to be used by the rubber companies in the United States of America alone to produce 66 millions of passenger car casings and 60 millions of tubes in 1946. 'By 1947 total rubber manufactures may soar to about 1·3 billion according to an estimate by the Committee for Economic Development.'

The question naturally arises whether the true rubber plantation will be started in India in other suitable places or not, of course eliminating the possibility of any future for the Indian rubber tree, *Ficus elastica* and *Cryptostegia grandiflora*. To this question my answer would be, if sufficient unused forest lands are available in rubber zone of South India or North-East and East India, such as the area along the border of Burma -say Chittagong Hill tracts-Manipore valley and southwards extending down to the Arakan bordering south Burma, the low ranges of Duars and Terai regions in the North-Eastern spurs of the Himalayan mountains and the Malabar and Coromondal hills in South India, these may be utilised for growing rubbers along with other timber and useful forest plants with a view to utilising them, rather than if and when emergency arises as experienced in the last global war, wasting time and money in exploring unnecessarily possibilities of obtaining inferior rubber from rubber trees of doubtful economic value. But optimism in dealing with such a variable industry as rubber should be taken with caution. Some of the biotic factors such as labour trouble, famine, economic standard of rubber workers, communication and several other factors influence the fate of rubber industry to a considerable extent.

I herefore agree with the following remark quoted from *Fortune* October, 1946:

Rubber men may be wrong again about supply this time with an over-estimate. The reason is not hard to grasp. The rubber growing regions, as well as other related areas of the East, were built up into an interdependent economy by slowly adding piece to piece. The natural rubber economy, as it existed before the war, depended for one thing on cheap, importable coolies. To feed them it depended on cheap rice. To clothe them it depended on cheap consumer goods, notably textiles from Japan. Even when all these productive factors are obtainable in far greater quantities than they are now, it will be no simple matter to put them together again.

'As for the coolies, the Japanese deported them by the thousands and worked many of them to death. In Malaysia, the labour force of the estates has been depleted to 40 or 50 per cent of pre-war strength. All rubber growing regions are short of cheap rice, the Burma-Siam rice bowl is disorganized. It may be years before textiles as cheap as the Japanese appear again in eastern markets. What is more, even the managers of the economy are no longer present in force. The Dutchmen cannot reach their estates in the most parts of Java, Sumatra and Borneo. In Malaysia, of the original 1,400 estate managers who were there before the war, there are perhaps only three or four hundred available.'

'Rubber may not come out of the East nearly so fast, or nearly so cheap, as some American observers seem to think.'

'In its days of ruin the Stevenson plant proved that rubber men cannot always foretell demand any better than they foretold supply. No sooner had supplies, unforeseen by the British, hit the market than the 1929 crash hit the United States of America. The automen of Detroit, whose needs had helped stimulate the boom, slowed down their assembly lines. Replacement demand for tyres fell off. By 1932 the price of rubber had dived to 3 cents. The moral drawn by the United States of America from the early phase of the Stevenson experience slack with the stretch in rubber prices. The moral drawn by the British from the later, low demand phase was that innocent bystanders were being hit by the United States of America depression. A moral that anyone can draw is that rubber has a habit of hitting men below the horoscope'.

I would therefore advise the Indian rubber lovers : ' look before you leap'.

ACKNOWLEDGEMENTS

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REVIEWS

FOOD PLANT SANITATION

By M. E. PARKER, [Published by McGraw Hill Book Company, pp. 447 Price $6]

IN this book the author has covered all important aspects of sanitary practice in food plants with a view to produce neat and wholesome food under neat surroundings. There are fifteen chapters covering the fundamental principles and various other sanitary aspects covering plant and equipment layout, water supply waste disposal, insects and rodent control, effective uses of detergents, fungicides, germicides, and sanitizers, effective methods of cleaning practice, training of 'sanitarians' and the ways of enforcing sanitary programme and the difficulties involved therein. Two chapters are included to cover the sanitary packaging practice and the sanitary aspects of packaging materials. A very useful inclusion is the appendix giving the important legal regulations covering food manufacture in the U.S.A.

It is a recognized fact that the public is entitled to protection from illness and death caused by eating impure foods. Consumers have also a right to get protection against practices which are offences to hygienic decency. This concept has been very conveniently included in the Federal Food, Drugs and Cosmetic Act of 1938 as 'a food shall be deemed to be adulterated if it consists in whole or in part of any filthy, putrid or decomposed substance or if it is otherwise unfit for food or if it has been prepared, packed and held under unsanitary condition whereby it may have become contaminated with filth'. In this comprehensive treatise the author has kept this in view throughout the discussion of the various principles and methods of sanitary control and inspection technique with a view to aviod legal action under the above provision of the Act and more so for giving the consuming public a healthy and wholesome food.

This book is a singularly useful compilation of the available knowledge in the branch of Food Plant Sanitation and is recommended as a reference or text-book for the Food Technologist, Plant Superintendents, Inspection Agencies, Public Health students and research workers. Every food industrialist in our country should go through this and set his hands and energy to the task of providing a neat and wholesome food from a neat surrounding. (G.S.C.)

SOIL EROSION—ITS PREVENTION AND CONTROL

[Published by the Government of Madras, 1948, pp. 177, Price Rs. 6]

THE rapid depletion of the soil resources of India by erosion and the subsequent effects in lowering the general standard of living of the masses has only recently been realized by the Governments in India. Any book, at this juncture,

which would create real interest in the country on soil erosion and its control is, indeed, welcome. The Madras Government is to be congratulated for having taken a bold step in bringing out a text book on soil erosion for the use of Departmental Officers and for teaching the subject in the Agricultural and Forest Colleges.

The subject matter of the book is divided into eighteen chapters and is profusely illustrated. Lessons of the past as well as of modern times of soil erosion have been presented in Chapter I. Examples of damage caused by erosion in different parts of the world have been cited. The chapter, begins with a definition of soil which is hardly apt. A definition of soil could have been more precise as the one given by Joffe. 'The Soil is a natural body, differentiated into horizons, of mineral and organic constituents, usually unconsolidated of variable depth, which differs from the parent material below in morphology, physical properties and constituents, chemical properties and composition and biological characteristics'. In addition to the description of the destructive processes leading to the accumulation of soil materials, the constructive aspect of soil formation leading to the development of soil profiles should have found a place.

Chapter II deals with the agencies and the types of erosion that are generally met with. The results of erosion in silting up of reservoirs and irrigation canals, reduction in underground water supply, etc. are also broadly dealt with. The chief causes of accelerated erosion are given in Chapter III. Nine causes are enumerated but only four of them have been explained in some detail. Under 'soil variable qualities', only the texture and the structure of soils have been dealt with. But other soil characteristics such as soil depth, permeability, nature of colloids, etc., which are significantly correlated with the erodibility of soils are not touched upon. An elucidation of these factors would certainly add to the value of the book.

Chapter V is well-written and contains much useful information. The question whether 'waste weirs' even in contour bunds, are necessary or not, is still a moot point. The intensities of rainfall as also the peculiar characteristics of the Black soils of the Karnatak do call for, if not waste weirs, some other mode of excess-water disposal. In Chapter VII, the items of dry farming and terracing have been discussed. Soil and moisture conservation problems are interdependent and a great deal of work has been done in India. Hence the subject of dry farming might have usefully been discussed in greater detail in this chapter. The subject of terracing could have been dealt with in more detail and also discussed in Chapter V along with contour bunding. Such important questions as the 'uniform grade' and 'variable grade' terraces, their length and cross sections should find a place in a text book.

Chapter X dealing with the agronomic or the biological aspect of erosion control has been treated cursorily. The effects of various types of mulches and the place of legumes and grasses in erosion control practices are not fully emphasized. The method of laying out contour strip cropping on the land, selection of suitable cover crops, their seed rate, width, which could be adopted with advantage in different soil types, slope, climatic complexes and their ultimate effects in soil development and increased crop production need to be dealt with in a text-book of this kind.

In the suggested land-use recommendations in this chapter, only slope and degree of erosion have been taken into consideration. A major factor such as soil type, which is vital for any land-use planning has been left out.

In Chapters XII, XIII and XV the question of types of dams and the control of stream and river bank erosion has been compiled very satisfactorily. The last chapter dealing with erosion and malaria although of vital importance to India occupies, for a text-book on soil conservation too much space. Lastly, in this volume, one vital omission, is a chapter wholly dealing with *soil conservation survey* of all cultivable areas including suggestions for land classification and land-use planning. No text-book could be considered complete without it. Otherwise, the volume is on the whole, timely, well written, definitely informative and useful. The subsequent volumes to follow on the subject may well be expected to be more comprehensive. The minor printing errors, not a few, are common with all our printers. (J.K.B.)

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MIXED CROPPING IN INDIA

By A. K. Yegna Narayan Aiyer, MA. (Madr.), N. D. D. (Eng.), Dipl. in Ag. (Cantab.), Director of Agriculture in Mysore (Retired), and Special Officer under the Indian Council of Agricultural Research, for the preparation of this article

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(With Plates XV to XIX)

PART I

GENERAL CONSIDERATIONS

THE practice of mixed cropping which forms the subject of this article is a peculiar and widely adopted method of cropping in India and one which may indeed be said to mark it off sharply from the agriculture of many other parts of the world. By reason of its widely prevalent character and the large variety of crops and conditions of farming that it covers its importance as a subject for scientific examination and research is as great if not greater than that of many other subjects which have been taken up for study so far. Its importance is greatly enhanced by the fact that it has to be studied from a number of aspects, both scientific and economic, demanding the co-ordinated work of specialists in many branches of agriculture. Moreover such opinions as have been expressed about the practice very few though they have been, are conflicting, some being favourable others quite the opposite. Its almost unique character as a form of husbandry also makes it an exceedingly interesting subject for research. A certain amount of attention has been devoted to it in the past by some of the Departments of Agriculture in the country which have touched some one single aspect or other, mostly the economic. It is a matter of some surprise therefore that the subject should have remained practically unnoticed in this respect for such a long time.

It is perhaps due to the special interest in the subject evinced by Rao Bahadur G. N. Rangaswami Ayyangar, I.A.S., formerly the eminent Millets Specialist of Madras and for some time Principal of the Coimbatore Agricultural College, who published several papers on the subject and stressed the need for a systematic study that brought the matter up for serious consideration. It was soon taken up by the Indian Council of Agricultural Research and was made the subject of a full discussion at the meeting of the Crops and Soils Wing of the Council in the year 1941 at its session held in New Delhi. The discussion was led by Rao Bahadur Rangaswami Ayyangar who was followed by several speakers each of whom dealt with one or more particular aspects of the subject as fully as the occasion would permit. The subject was considered worthy of further study and experiments and to this end the following resolutions were adopted viz., ' The Crops and Soils Wing recommends that Directors of Agriculture in the various provinces and States should : (1) make a list of the mixed cropping practices prevailng in the different

areas within their jurisdiction, indicating the usual proportions in which the crops are mixed and the normal soil and the rainfall conditions of the areas concerned and communicate the same to the I.C.A.R. for further examination by a suitable committee; (2) undertake experiments designed to compare the yields and economic results of growing the crops in question (*a*) pure, (*b*) mixed in the usual proportions, (*c*) mixed in other proportions and (*d*) their effect on soil moisture; (3) during the course of these experiments carry on observations to study the interaction of the crops at all stages as regards (*a*) root competition, (*b*) competition for air and light above ground, (*c*) nitrogen content of the soil, (*d*) attack of disease and pests, (*e*) soil moisture content, (*f*) quality of produce and (*g*) protein content.'

In accordance with recommendation (1) above, lists of mixed cropping practices prevailing in the different provinces and States were prepared and furnished to the Council, a task which must have cost much time and painstaking labour to the departments concerned. At this stage it was considered that an article on the whole subject embodying all the information that may be available on the subject together with the accounts of the mixed cropping practices collected and furnished to the Council would prove very useful in connection with the scheme and should be prepared. I had the honour of being invited to undertake the preparation of the article and on my agreeing to do so, the Council conveyed formal sanction to the work being taken on hand in their letter No. F.57/2/42-A, dated the 14th March 1944. This is roughly the background for the preparation of this publication.

The complete file containing the lists of mixed cropping practices received from the different provinces and States was sent to me as well as a copy of the proceedings of the meeting containing abstracts of the speeches made during the discussion. These speeches cover a wide field, touch nearly every aspect of the subject and have been made by scientific specialists and by experienced practical agriculturists hailing from many parts of the country. Their observations form very valuable material and indeed have served as the broad framework which I have tried to fill in. As the abstracts were found very brief and as I considered that the authors might desire to amplify them or correct inaccuracies, I forwarded the extracts to the respective authors, from some of whom further information was also received, more especially in respect of references to published work. All these have been very helpful. The lists of mixed cropping practices constitute somewhat voluminous material containing a mass of relevant information and are probably as comprehensive each in respect of the territory concerned as it may be possible to make it. The information has generally been furnished in tabular form under the different heads specified in the recommendation of the meeting. They have been received from the following provinces and States: the N.W.F. Province, Kashmir, the Punjab, the United Provinces, Bihar, Bengal, Assam, Sind, Bombay, Bhopal, Gwalior, the Central Provinces and Berar, Hyderabad, Orissa, Madras, Mysore, Cochin and Travancore and cover therefore almost the whole of India. These lists have been studied and in respect of many of them further information was also sought and obtained from the respective departments on all points requiring clarification. This large mass of information has been analyzed and the material rearranged and presented with

explanatory remarks regarding special features. This rearrangement is grouped under the main crops of the country, showing with what other crops in what numbers and in what proportions they enter into mixture. They specify for instance, two crop mixtures, three crop mixtures and mixtures with more than three crops, whether these are cereals pulses or other crops, the total number under each of these classes, and in the case of the two crop mixtures the various proportions in which they are mixed. This special treatment has been made in respect of only the main crops and in regard to proportions is limited to the two crop mixtures, from considerations of practical importance, not to mention those of space.

Such literature as could be obtained on the different aspects of the subject meagre though this is, has been consulted and made use of. All the Directors of Agriculture who were consulted to ~~ascertain if~~ any experiments have been conducted on the lines suggested in recommendations (ii) and (iii) of the Council have replied in the negative. Only the few experiments conducted in the past and prior to this discussion have therefore been available and these have been fully utilised and are referred to in the appropriate places. These experiments relate mostly to the Madras and Bombay Presidencies, the Central Provinces and Mysore State. All these sources of information together with such facts as I could gather from my own studies and as have come within my experience as an agricultural officer in Mysore and outside have formed the materials for this article. Wherever necessary and possible the concerned references have been quoted.

The general plan of the article will be seen from the headings given in the contents. The article is divided into two parts, Part I General and Part II Special. Part I describes the forms of mixed cropping and the extent of the practice as compared with pure cropping and the methods of sowing the mixed crops, and then deals with the various different aspects of mixed cropping each in a separate section, viz., mixed cropping in relation to rotation of crops, soil moisture, plant foods, association of cereals and legumes, insect pests and diseases, the use of labour saving implements, balanced nutrition, insurance against crop losses and utilisation of space ; a section on the economics of mixed cropping closes this part. In the main these relationships are the ones which are specified in the Council's recommendations (ii) and (iii) and which have formed the principal heads in the discussions ; they have been accordingly adopted by me as a helpful basis.

Part II contains what I may term the factual foundation for the article. It is devoted to a description of the details of mixed cropping with reference to the chief crops, together with certain relevant observations. These chapters form really a digest arranged according to crops, of the information contained in the lists furnished by the Directors.

Illustrations showing the implements used for sowing mixed crops and fields with mixed crops standing, which have been kindly supplied at my request by some of the Directors of Agriculture have been added. These views relate, it will be seen, to many parts of India and will no doubt be appreciated by readers, both in and outside India.

A somewhat embarassing task has been in connection with the names of the different crops. Each province and State has used its own vernacular and the same crop has been referred to by many names. It has been rather difficult under these circumstances to fix upon any one vernacular or common name for being used throughout. My selection had perforce to be somewhat arbitrary and I trust this will be condoned by readers who may be accustomed to a different vernacular. A full glossary giving the botanical names and the different vernacular names and the common English names where possible has been furnished by each Director with regard to his particular region and this has been added as an appendix.

As one who has ceased to be in active service now for many years I regretfully admit that the article is not as thorough as it might perhaps otherwise be. I have found the work however of absorbing interest and that, together with the hearty co-operation which has been extended to me by the officers of all the Departments of Agriculture to whom I applied have enabled me to make the work as satisfactory as I could. Mixed cropping is a large and unique part of crop husbandry in India and I trust I have furnished a comprehensive connected and readable account of the practice in its various aspects and as it prevails in most parts of the country.

Forms of mixed cropping

In a general way we may define mixed cropping as the system of growing two or more crops (or varieties) in the same field, garden or plantation, not in separate blocks each carrying a single crop but all of them mixed together and occupying jointly the same ground and sharing in common the cultural operations of the field as though the latter were intended for one single crop, and sown or planted either promiscuously in the midst of each other or systematically in alternating rows or otherwise. The cropping may apply to permanent crops of the so-called plantation type or those which occupy the ground for only one crop season whether this be a few weeks, months or a year. The cropping may apply again to a mixture of both these two types of crops, permanent and temporary, the latter being grown either for the sake of its produce or for being ploughed in as green manure or for both. In particular, it is to the temporary or annual crops and even among them to the crops grown on a field scale and comprising the ordinary field crops that the term shoud be confined ; as a matter of fact the large amount of data collected and dealt with in this report relate mainly to this class of crops, and to the systems followed in cultivating them as mixed crops. A brief description may however be given of the mixed cropping methods of the other types also, both for the sake of completeness and for its value in illustrating the principles which underlie the practices.

Mixture of permanent crops

The most common example of this practice can be said to be the mixed fruit

gardens, in which cocoanuts, mangoes, jack, guavas, oranges and other citrus trees mingled with arecanut trees, and all planted generally in a promiscuous manner and very often too crowded to permit of the different trees yielding their best are grown together. These gardens are generally irrigated or (as in some parts of Mysore) are subject to periodical inundations from rivers which overflow their banks. All the cultivation is only by manual labour and this takes the form of a digging once a year at the close of the monsoon. Manure may be carried in headloads and applied, or the yearly addition of silt by the river may be all that is considered necessary. Depending upon the varieties of the trees planted, there is a succession of crops of one kind or another almost throughout the year with of course flush periods now and then. There is also work of one kind or another in the garden throughout the year to occupy the time of the grower. The gardens are highly valued on this account and there is always the temptation to plant something or other extra, a fruit or flower for sale or the owner's enjoyment. The gardens are fully shaded, the crowns of many trees mingle, others carry their canopies higher, resulting in two or more tiers at irregular heights.

The second example is furnished by certain kinds of coffee estates, specially of robusta coffee ; in these a few rows of robusta bushes varying from three to six may be seen planted alternately with one row of oranges, to which may be added a row of pepper trained on shade trees, so that three permanent crops alternate with each other in systematically planted rows. In many coffee estates indeed pepper is a regular feature, growing however trained on the shade tree standards either in a somewhat promiscuous manner, or in regular rows. While in the larger estates, pure crops are the rule with the exceptions noted above such as the growing of pepper and oranges, on the smaller gardens and estates, especially in Travancore, and Ceylon, may be seen quite a mixture of trees as in the irrigated gardens referred to already. These may comprise cocoanuts, arecanuts, cloves, cocoa, coffee and even tea bushes in case there should be a factory near by.

A third example is the growing of the areca palm with the betel vines trained on them as standards. The shade of the areca palms which are planted very close helps the betel vines for which shade is indispensable while the trees themselves furnish the standards for the vine to climb upon. The heavy manuring, irrigation and constant attention received by the betel vine greatly benefits in its turn the areca trees themselves. An example of a different type is furnished by the arecanut gardens of the malnads of Western Mysore, S. Canara and the Konkan, which are unique in respect of the planting and cultivating methods. Areca, cardamoms, pepper and plantains are the crops grown and they are planted in such a way that hardly any ground is wasted Areca trees are planted in roughly three instalments, at intervals of about seven years or ten years, so that they stand about six feet apart in regard to their bases but their crowns are quite clear of each other being almost 15 to 18 feet apart. The trees are thus of three age groups, each group being about seven or ten years older than the one following it in time. When the trees have grown about 15 feet high (exclusive of the crown) pepper vines are planted

under them and eventually trained on the stem as standard. When the garden is ten years old the planting of cardamoms is taken on hand and these are planted all along the margins of the drains, and by periodical renewals these are kept up permanently. Plantains are planted even before the areca is put in, as a preparatory crop to shade and nurse the young areca trees and every year thereafter are systematically kept up by new plantings in between the areca trees, so that there is hardly any vacant space except what is occupied by the drains and the narrow elevated ridges which separate the rows of areca trees and which serve as pathways. The procedure defining exactly the routine of yearly plantings manuring, cultivation attention to drains and ridges is fixed and committed to writing and lease deeds specify the duties of the lessee in detail. This is perhaps the oldest and most clearly defined form of mixed cropping in respect of permanent crops.

Mixing permanent and temporary crops

The temporary crops grown mixed with permanent crops are in the nature of (1) nurse crops, (2) catch crops, (3) green manure crops.

(1) *Nurse crops*. This may be exemplified by the growing of crops like 'bogame dalloa' (*Tephrosia candida*) Crotalaria spp. like striata, juncea, anagyroides *Sesbania aculeata* and such crops between rows of young coffee, and to some extent also tea. These furnish a certain amount of low shade, protecting the young bushes ; they may be removed after a season but are generally kept on for a year or two, being lopped in the interval if necessary, so that the growth of the main crop may not be interfered with. The loppings act also as a green manure and as a soil mulch.

Another example is the growing of plantains in young cocoanut gardens, principally for the sake of protection against the sun. At the same time they serve as profit yielding crop for some years until they have to be removed in the interests of the cocoanut crop itself. Till then by yearly new plantings the plantains are kept on, with advantage to the cocoanut crop and just paying for the expenses of cultivation. It is sometimes claimed that the plantain crop keeps away the rhinoceros beetle from the cocoanut palms ; if it really does so it acts as a nurse crop in more senses than one. A trial was made by the Mysore Agricultural Department to test this point by planting a plantain sucker under every alternate cocoanut plant in the Hebbal Farm but the results showed no difference in regard to the incidence of the attack ; still the belief is somewhat general.

(2) *Catch crops in the midst of permanent crops*. These crops are of very short duration, especially in comparison with the main crop, and are grown until the main crop comes into bearing and only during such time that they can be grown satisfactorily and without detriment to the main crop. They are cultivated for the sake of their produce, and yield a small income, which may often be sufficient to meet the cost of cultivation of the main crops. In young cocoanut gardens, *ragi* (*Eleusine coracana*), *jowar* (*Andropogon sorghum*), Italian millet (*Setaria italica*), groundnuts, or one or other of the many kinds of the quick growing pulse crops like blackgram (*Phaseolus mungo*), greengram (*Phascolus radiatus*) or horsegram (*Dolichos biflorus*) are grown in this manner. A notable practice under this class is the growing of

vegetable crops in among betel leaf gardens ; these gardens are kept up for either a period of three years (in South India) or indefinitely for a long period of even 20 to 30 years (as in Mysore). The gardens are heavily manured and watered. The ground under the vines and the advantage of the intensive cultivation are utilised for the growing of short duration vegetables which yield an income till the vines begin to yield and as long as they can be grown without interfering with the cultivation or yield from the vines.

A third and notable example (although it does not relate to a permanent crop, like the ones considered so far) is the growing of catch crops in the midst of young sugarcane. Where sugarcane is planted on elevated beds about six feet wide and divided by trenches, these beds are sown with radishes, greens, coriander, onions, French beans, etc. and these crops are gathered within 45 to 60 days, and removed. It means a profitable utilisation of the ground without detriment to the sugarcane. The kind of crop to be grown has to be carefully selected for if they are tall growing they are likely to check the growth of the sugarcane. It was once advised that sannhemp (*Crotalaria juncea*) may be advantageously grown in this manner and in preference to the vegetable crops, to be later pulled out and laid on the beds as green manure ; but in many cases this crop was found to check the growth of the cane. The practice was not taken up owing to this risk.

Young orange gardens or plantations, especially under irrigation are systematically inter-cropped with vegetable crops or even cereal crops during the first few years in order to make some profitable utilisation of the ground between the rows of the orange plants whereby a moderate income is realised which may cover the cost of cultivation if not yield a small nett profit. This inter-cropping ceases as soon as the orange plants become bushy, when the irrigation basins have to be enlarged and the inter-spaces will not allow of any such inter-cropping. All through the newly developed *Santra* groves of the C.P. and Bombay and the Northern Circars this kind of cultivation with mixed crop is very general. The same practice obtains in gardens of papayas, although in this case it is only for a year or two as the papayas themselves remain on the ground only for about three or four years.

(3) *Green manure crops.* Some of the crops belonging to above class may comprise green manure crops which in contrast with the former are merely dug or ploughed in and not allowed to mature a crop for sale and conversion into money. The practice is perhaps not a general one, but is adopted wherever it may be considered necessary and advisable to do so, taking into consideration other factors mainly the supply of soil moisture and rainfall. Special mention deserves to be made under this class of the practice which is becoming very prevalent in recent years in rubber estates and which consists in the growing of green manure crops like *Centrocema pubescens, dolichos pueraria phaseoloides*, cow-peas (*Vigna catiang*) or other low growing leguminous crops for this purpose and incorporating them into the soil ; the last mentioned crop viz., the *Centrocema pubescens* acts also as a very good cover crop and is left on the ground almost as a permanent crop where it seeds and regenerates itself naturally. The fairly wide expanse of ground surface between the rubber trees makes such a cropping convenient and the growth of these mixed crops

is usually very heavy and form a very thick cover on the soil. As to the practical advantages of the method as against clean cultivation and ordinary manuring, views differ but we are here referring only to the existence of the practice, the other aspects being dealt with separately.

Mixed cropping with fodder grasses

In quite a separate class comes the sowing of grass seeds and of leguminous fodder grass seeds mixed together for grass land intended to be under permanent or temporary pastures. Both the types of grasses grow together and are mown together and converted into mixed hay, or/and grazed together. This association of not only different grasses but also the legumes with the grasses is advantageous not only in improving the nutritive value of the mixed forage, but may be also said to possess most of the special advantages of mixed cropping such as an assured yield free from seasonal risks, a better utilisation of the soil and also mutual benefit to the different components. It is in fact in connection with these grass mixtures that considerable scientific work on some aspects of mixed cropping has been carried out. Such mixtures are also practised in the case of fodder crops grown as ordinary field crops of one season; a common mixture is that of fodder *jowar* with horsegram to be cut and fed together as green feed. There is likewise the mixture of fodder *jowar* and berseem (*Trifolium alexandrinum*), *shaftal*, cluster beans (*Cyampsis psorialioides*) (*Trifolium resupinatum*) and such other leguminous crops, all meant as mixed green fodder.

Extent of mixed cropping

The extent of mixed cropping is very large and certainly forms a conspicuous feature of agriculture in India, so much so that to the observant visitor this is the most striking and interesting feature which marks it out sharply from cultivated areas of Europe or America, and which immediately sets him thinking as to what may be the rationale of such a peculiar feature. Depending upon the temperament of the visitor it is put down to ignorance of the importance of rotation of crops or as a remarkably clever adaptation to the needs of the country full of practical wisdom and worthy of deep study. Though the extent is large and striking it must not be thought that it is universal or that it is invariable and carried on to the exclusion of pure or single crop cultivation. There is no correct information regarding the relative extents of pure and mixed cropping in the different provinces, but from the approximate data furnished by the various departments of Agriculture it may be stated that large as the extent may be, it is however only a fraction of the extent of mixed cropping. For one thing the practice of mixed cropping is largely if not wholly confined to rainfed or dry cultivation, and barring minor exceptions under well cultivation, for example, and some special cases all the irrigated crops are grown pure. Even under dry cultivation there is a very large extent of pure cropping with the very same major crops which figure in mixed cropping. Moreover such information as is available indicates that in some provinces mixed cropping is very insignificant. Thus in the province of Sind it is reported that 'mixed

cropping is not much in vogue in this province. It is only in stray tracts the combination of cotton with *jowar* and *guar* is noticed.' In Jammu and Kashmere it is reported that 'the exact acreage under this mixed cropping is not known but it may be assumed to be about 5,000 acres,' which is certainly very small. In Travancore and Cochin the practice is confined to certain taluks only. In the west coast districts of the Madras Province also i.e., Malabar and South Canara it is stated 'no regular mixtures are grown worth mentioning.' In the report on mixed cropping methods received from the Bombay Province, the West Coast Districts do not figure much at all; in the Malnad Districts of the Mysore State, where the rainfall is as heavy as in these West Coast Districts and rice is the chief crop grown no mixtures are practised. In the report from Bengal, it is stated that in the District of Dinajpur the practice is not much in vogue. In the districts comprised of the Western Circle, Bengal, the extent of mixed cropping in the case of the following crops is reported as under: paddy from 5 to 30 per cent, wheat from 2 to 12 per cent, barley 1 to 25 per cent, gram 15 to 77 per cent, lentils 20 to 77 per cent, peas 1 per cent, *khesari* 20 per cent, *mung* 2 to 20 per cent, mustard 1 to 50 per cent, potatoes 1 to 5 per cent. In the Jullundur Circle, Punjab, mixed cropping amounts to only 15 per cent in cotton, 20 per cent in *jowar*, 20 per cent in maize 10 per cent in *bajra*, 40 per cent in barley, 60 per cent in wheat and 80 per cent in gram. In the Districts of Bihar comprising the *Chota* Nagpur Range, it is stated that mixed cropping is not much in vogue. Even in a province like Madras where the practice is very important, mixed cropping is by no means the rule and it is stated that the ratio of pure to mixed cropping is subject to variation from year to year. In Gwalior State it is reported that the ratio of the acreage of crops grown pure to that of the same crops grown mixed are as in Table I.

TABLE I

Ratio of pure to mixed crops

Serial number	Crops	Ratio of	
		Pure	Mixed
1	*Jowar*	1	1
2	*Bajra* (*Pennisetum typhoidem*)	1	1⅓
3	Cotton	1¼	1
4	Ginjelli (*Sesamum indicum*)	1	2
5	Maize	2	1
6	Wheat	1	1
7	Gram (*Cicer arietinum*)	1	1⅓
8	Barley	1	4
9	Linseed	13	1

Even where mixed cropping is largely practiced many crops are thus grown both pure and as mixed crops. Thus very large areas may be seen where *jowar*, wheat, *bajri*, *ragi*, cotton, castor, gingelli, the different pulses, dry-land chillies etc., may all be seen to be grown pure, although they are the chief crops which are grown as mixed crops.

It may be interesting to note the circumstances which sometimes decide the pure cropping of even those crops which are largely grown with a mixture. In Mysore, in the tracts of early rainfall where the *ragi* called *kar ragi* is grown, it is sown pure, as this enables the field to be ploughed in the late rains, after the harvest of the *ragi*, in which condition the field remains until sowing season next year. Whenever *ragi* is grown by transplanting whether as a dry crop or as an irrigated crop it is grown pure, so as to make it possible to intercultivate the field both along and across, as the plants are transplanted in regular chess board fashion. For the same reason crops like castor, chillies and tobacco although they are sown in the main season and form the only crop of the year are also grown pure. When two crops are raised in the same year one in the early rains and another in the late rains, these are raised generally pure. The pulses like blackgram and greengram are grown pure in this way either in the early or the late rains; the pulse horsegram is grown in the late rain, as likewise Bengal gram. Fodder *jowar*, short-season groundnuts (Spanish or Small Japan) are sown in the early rains pure, because the land has to be ploughed and sown with a second crop in the late season. The late season *jowar* (called *bilijola* in Mysore) is also sown pure, invariably. In all the cases the need for getting the field ready for a late or second crop, and the fact that this second crop has to be of short duration depending as it does upon only the stored moisture of the soil and very little on rainfall, restrict if not preclude the sowing of a mixed crop, one of which may be of long duration and may not therefore thrive on account of lack of rainfall. Among the main season crops which occupy the field the whole season, the American Cotton (called Dharwar American) is grown only pure unlike the local cotton which is grown both pure and mixed. The trailing varieties of groundnuts, also a main season crop and the only crop of the year, is only grown pure. The reason probably is that these two are crops introduced newly into the country (although they have been grown now for probably a century) and have not shared the tradition of mixed cropping unlike the old indigenous crops at any rate so far as Mysore is concerned. It must be mentioned however that elsewhere as in Madras, these are grown both as pure crops and as mixed crops. Thus pure cropping methods prevail over very large regions, even in the case of dry crops (where alone mixed cropping assumes importance) and in respect of the crops which largely figure in mixed cropping and in the case of many short season crops which on this account may be considered fit only for mixed cropping.

Mixed cropping and crop rotation

Some of the remarks made by those who have written in high appreciation of the practice of mixed cropping may lead one to suppose that the system is to be

regarded as a substitute for a rotation of crops and that these mixtures are grown year after year in the same field, because this is a 'tabloid form of rotation,' that it helps more than anything else to maintain the fertility of the soil and so on. As a matter of fact on the other hand the need for and the advantages of a rotation of crops, and conversely the incorrectness of growing the same crops or the mixture of crops on the same field year after year are fully appreciated and it is very doubtful if the system of mixed cropping is adopted because rotation is considered unnecessary under that system. This is clear from the fact that excellent systems of rotation suited to the different local agricultural conditions are everywhere in vogue and are adopted in conjunction with mixed cropping. Dr Buchanan at the outset of his tour when he first noticed a mixture of crops observes that 'the cultivators do not seem to understand the ameliorating effect of rotations' but as the tour progressed and he traversed a large extent of country he has occasion to notice that the contrary is the case and that elaborate rotations are known and followed and with his usual thoroughness he records these rotations. It may be interesting to note down some of these:—'Round Pollachi (Coimbatore District) the following rotations are common viz., first year *bajri* with its mixed crop of pulses, second year *jowar* in the first season followed by horsegram in the last season, third year grass manured by folding with cattle. (*b*) First year *bajri* with its mixed crop, second year *jowar* in mixture with *Panicum miliare* or blackgram or gingelli or green gram in the early season followed by horsegram in the late season, third year grass manured by cattle folding, (*c*) first year *bajri* with its mixed crop, second year cotton with *jowar*, third year cotton of the previous year remains over, fourth year grass manured by cattle folding.

In Mysore similar elaborate rotations are common, although the mixed crop of *ragi* with which field beans (*Dolichos lab lab*) is grown year after year on the same field to a very large extent. A full account of the common rotations is given in the author's book '*Field Crops of India*.' Some of these may be extracted here: viz., in the cotton belt, cotton either local *G. herbaceum* or American is grown pure and is followed by *jowar* grown pure or with a mixed crop of redgram (*cajanus indicus*) but generally a variety of crops including redgram. Where only late season crops are possible, in the black cotton soil belt, cotton mixed with Italian millet is followed in the next year with either late season *jowar* or Bengal gram or wheat. In the red soil *jowar* tract of the Mysore District *jowar* with redgram as a mixed crop is followed by early season *ragi* in the next season, or by mixture of horsegram and niger. After *ragi* with its mixed crop of field beans or redgram or a mixture of several in the first year may come in the next year either the same mixture or short season groundnuts followed by fodder *jowar* in the same year or long season groundnuts only; in the second or third year only horsegram may be sown or a double crop of fodder *jowar* followed by black or green gram. For nearly every crop whether grown pure or in mixture there is an appropriate rotation crop. These rotations are always followed except where conditions force the *ryot* or make it financially advisable on account of high prices for some produce, to resort to the cultivation of the same set of crops without a change.

Information regarding the rotations prevailing in many of the provinces is given in Appendix III and some are extracted below:

Bhopal. The general practice is first year wheat, second year cotton or *jowar* third year gram. 'There are cases where due to special circumstances they do get away from this rotation but it is only either in a part of the holding or in places where they cannot grow a particular crop due to some reason.'

North West Frontier Province. The following are some of the rotations: (1) Maize—wheat—maize, (2) rice—*shaftal*—maize, (3) wheat—cotton—wheat, (4) gram—*bajra*—gram, (5) maize—berseem—maize, (6) *rice*—wheat—rice, (7) gram—*bajra*—*toria* (*Brassica napis*), (8) maize—tobacco—maize, and (9) wheat—fallow—wheat.

Bombay Province. Mollison's Text book of Agriculture gives the rotations for nearly every crop of importance and it will be seen from his account what a systematic rotations of crops is practised. The following are some of these: (1) *jowar* with mixed crops—cotton, (2) *bajri* with mixed crops—Italian millet or *sundhia jowar*, (3) *bajri* with mixed crops—*jowar* or niger, (4) *bajri* with mixed crops—cotton, (5) wheat cotton—*jowar*, (6) wheat—linseed—gram, (7) *ragi* with mixed crop—*jowar* with its subordinate mixed crops—or Italian millet mixed with redgram and gingelli, (8) sesamum—cotton—*jowar*, (9) niger—hill millets.

A similar condition probably prevails throughout the country, and reports from the provinces concerned give details about the rotations. The point to note however is that along with the mixed cropping system and as part of it regular rotations are practised in which the group of mixed crops of any one particular year is taken as a unit, and is followed by another single crop or group of mixed crops as in any ordinary rotation. The growing of the same crop with its appropriate mixture year after year without a rotation in the same field though practised very largely and in many tracts must be considered special, and should in no sense be taken to mean that rotations are either unknown or not practised and that mixed cropping is adopted as a substitute.

Although it is needless to labour this point further, the following remark by Dr J. A. Voelcker may be found both interesting and valuable, viz., 'It is quite a mistake to suppose that rotation is not understood or appreciated in India.' Dr Voelcker also gives in support of this observation numerous instances of the rotations practised systematically in the provinces of the Punjab, the N. W. F., Bengal, Central Provinces, Bombay and Madras (*Improvement of Indian Agriculture*, pp. 234-236).

HOW THE MIXED CROPS ARE SOWN

The methods of sowing adopted in the different provinces show interesting variations depending upon the general level or excellence of the agricultural practices

current in each tract and also on the condition of the soil at the time of sowing. These methods comprise the following:

(a) *The sowing is entirely by the method of broadcasting or scattering by hand.* Both the main crop and the crop or crops used for growing in mixture are sown broadcast in this method. In broadcasting itself more than one method is adopted, viz., (1) the seeds of the two kinds of crops are mixed together and the mixture is sown broadcast, and (2) the main crop is first sown broadcast by itself and the field is given a light ploughing or harrowing to cover the seed; then the mixed crop is sown in the same manner i.e., broadcast and the field lightly ploughed harrowed to cover the seed. This latter practice of sowing the mixed crop after finishing the sowing of the main crop is followed in the case of those crops the seeds of which differ very much in size. Usually the smaller sized seeds are sown in the first sowing and the larger sized seeds are sown in the second sowing. This method of double sowing is adopted in order to secure uniformity in the distribution of the two kinds.

(b) *The second method consists of both broadcasting and line sowing.* The main crop generally, a grain crop, is first sown broadcast and covered by a light ploughing or harrowing, then plough furrows are drawn at the desired distances and in these furrows the seeds of the mixed crop are dibbled or dropped by hand. In the alternative the opening of the furrows and the sowing of the seeds may be done in one operation by the use of a one-row drill; this is tied behind the plough which goes in front opening the furrow, while the seed is dropped through the drill. The mixed crops very often comprise more than one, and then the seeds of all these are mixed and sown in the plough furrows either by hand or through the one-row drill. The broadcasting of the main crop in this manner is adopted even where line sowing is the general practice, when the soil may be too moist and the openings of the seed-drill tynes may become choked with soil and the sowing may become imperfect leading to bare unsown patches here and there.

(c) *The sowing may be entirely in rows.* Both the main crop and the mixed crops are sown in lines in this method. This kind of sowing in lines is done almost invariably with the help of seed-drills of various kinds, including the above mentioned one-row drill. The simplest among these practices consists in using only the one-row drill. This is tied behind a plough, which moves forward opening the furrow, into which the seeds of the main crop are dropped through the hopper of the drill. After the customary number of rows of the main crop have been sown, then one row, (sometimes more) of the mixed crop is sown through the same drill, after which the sowing of the main crop rows is resumed; the same is repeated till the whole field is completed. The implements used in this method are only two, a plough and a one-row drill. As in the several methods of sowing in rows, in this method also the rows

may be pure or may themselves consist of mixtures. In the latter case the seeds of the different kinds are mixed together in the desired proportions and sown.

In many provinces and tracts the general level of agricultural practices is somewhat high and in these regions a variety of implements for both tillage and sowing is in common use. Sowing is systematically in lines and when mixed cropping is adopted seed-drills of many kinds, some with two, some with three, four or six and one type with even twelve tynes are used, for sowing the main crops., The mixed crop is sown through a one-row drill. The exact method of sowing by which with the use of the one-row drill and one or other of the multi-row drills a definite number of rows of the main crop are made to alternate with one row of the mixed crop is very elegant in its cleverness and simplicity. At the first, second or third journey of the multi-tyned drill an appropriate hole in its hopper is plugged and behind the corresponding tyne the one-row drill is fixed and brought into operation until the one row of mixed crop is finished; in the multi-row drill the plug is now removed, the one-row drill is disconnected and the sowing of the main crop through the former with its full number of holes resumed. This alternate working and idling of the one-row drill is repeated regularly until the field is sown completely, resulting in the alternation of definite rows of the two kinds of crops with each other with great regularity.

The twelve-tyned drill of Mysore is used for sowing *ragi* and with the addition of a one-row drill eleven rows of *ragi* are sown alternating with a mixed crop generally field beans, but sometimes redgram either pure or mixed with other minor crops like the various pulses, mustard or niger, etc. With a three row -drill used with a one-row drill two rows of one crop or five rows of the same may be made to alternate with one row of the mixed crop. Drills are made with two, three, four, five and six tynes, in different parts of the country and the one with twelve tynes described above is exceptional and can be seen perhaps only in Mysore.

The sowing of the main crop is carried out by feeding the seeds through the hopper which may have one or more holes corresponding to the number of tynes or rows which the drill is to sow; these holes are usually very small and will not admit of larger seeds like groundnuts, Bengal gram or cotton being sown especially if the number of rows to be sown by the drill exceeds two or three; in these cases the holes are made larger. As an alternative and where more rows than two or three are to be sown, then a one-row drill is attached behind each of the tynes of the drill, the seed is then fed into each of these, for the hopper of these is quite large almost like a bowl and can take even large seeds like castor. In these cases the hopper of the main drill and the seed tube fixtures are removed and the drill is used only as a furrow opener.

In a great many cases instead of keeping the rows pure whether they be of the main crop or of the mixed crop, a mixture of seeds is sown in the rows themselves, so that the rows themselves have a mixed population of more than one crop. For this purpose the seeds of the different crops are mixed before sowing in the customary proportions and are then sown in rows through the drills. Such mixtures are sown

2. How does the legume increase the nitrogen content of the cereal ?
3. Does such increase extend to the grain and also show itself as an increase in the protein content of the grain ?
4. Does one legume differ from another in its capacity to increase the growth of the cereal ? And conversely does one cereal differ from another in its ability to take up and be benefitted by the nitrogen furnished by the roots of the legume ?
5. How does the yield of the cereal in mixed cropping compare with its yield grown pure ?
6. What exactly is the method by which the favourable action of the legume is imparted to the cereal, is it the mere decomposition of the legume roots or nodules or is there any definite product excreted by these organs, capable of being easily assimilated by the cereal roots and lastly,

7. What, if any, is the optimum proportion of legume to the cereal in the mixture ?

We must refer readers to Nicol's detailed summary for a full account of the work and conclusions on all these matters, upto the time that he wrote, and to papers by other authors for the details of their work. We shall only give a very brief extract of the conclusions.

How does the legume affect the growth of the cereal ?

Lipman gave experimental proof of the ability of some non-legumes to secure an adequate supply of nitrogen when growing together with some legumes in sand devoid of nitrogen. This however was not found to apply when the legumes concerned were cowpeas or soyabeans. In fact, as pointed out by Modhok, in 20 out of 26 cases reported Lipman did not find any beneficial action of the legume on the non-legume. Other earlier workers like Tacke, Lyon and Bizzel, however, noticed and reported the beneficial action of the legume on the non-legume. Stallings [1926] working on a mixture of wheat and soyabeans 'failed to establish any, very evident benefit derived by wheat from the legume'. Gurski [1927] found that the growing of vetches along with barley and oats led to increased yields. A great amount of work on the subject has followed since, most of which from Helsinki in Finland and Rothamstead in England. This work has led to 'less exceptionable indications that a legume, when well supplied with its proper nodule bacteria and with phosphate and potash, can obtain from the air not only sufficient nitrogen for its own needs but so much more as to satisfy the nitrogen requirements of at least one suitable non-legume plant grown beside one legume' (Nicol). The most notable positive conclusions were from the work of Virtanen and his associates, who have worked with oats and peas, with red clover and meadow foxtail, barley and peas. Working with lucerne and Italian rye grass, Nicol and Thornton found that 'given a small initial dose of nitrogenous manuring the grass when grown in association with the lucerne, contained nitrogen several times more than was supplied in the shape of manure ; also that grass grown with the lucerne even where it received no

starting dose of nitrogen contained twice as much nitrogen when grown with lucerne than when grown without lucerne '.

Field experiments however (reported by Nicol) are not very conclusive. Experiments at Rothamstead on oats—vetches are said to have suffered from rather an unfortunate choice of land. It is stated that Danish experiments in undersowing oats with legumes showed that the increase in grain ascribable to the legumes (red clover and serradella) was small over an average of years. In the 1932 experiment with oats—vetches mixture (when no nitrogenous manure was applied) the yield of oats both grain and straw was higher when the crop was pure than when it was grown with vetches. In field experiments carried out by Lyon [1925] using oats and peas the conclusion is drawn that the mixture is detrimental to oats in as much as the yield of grain was always higher in the pure oat crop than in the oats—pea mixture. According to Nicol these experiments are not free from drawbacks, which may vitiate the conclusions.

A number of experiments on the effect of soyabeans and cowpeas on maize appear to show that the legumes depress yield of the maize. It should be added however that in one set of experiments (Brown in Lousiana) which were carried out over a series of five years, it was found that though in the first two years the yields of maize in the mixture were less than in the pure maize crop, in the last two years the result was the exact reverse, which may be taken to indicate that over a series of years the mixture may be favourable.

Work in the Punjab by Modhok [1940] on the association of chick pea (*Cicer arietinum*) with wheat of *senji* (*Melilotus parviflora*) with oats and of *guara* (*Cyamopsis psorialandes*) with *chari* shows that the mixing was favourable neither to the grain nor the legume. Chick pea suffered both in growth and in nitrogen content, to the extent of 35 to 40 per cent in size and 12 to 20 per cent in weight ; while the beneficial effect on the wheat was neither marked nor constant. So did *senji* in association with oats to the extent of 60 per cent in height and 80 per cent in total dry weight, with no gain on the part of the oats ; in respect of the *guara-chari* mixture however, the *chari* is definitely benefitted but there was the same depressing effect on the growth of the legume.

The depressing effect on the legume in association with a non-legume was also noticed by Virtanen, who found that in mixtures of peas with non-legumes (like barley, oats, wheat and potatoes) with increasing ratios of non-legumes to legume the growth of the peas suffers, obviously, as Virtanen remarks, from lack of nitrogen due to the fact that the non-legumes snatch away the nitrogen fixed by the legume before it could be made use of by the legume. Modhok also refers to a similar effect of the ratio of the legume to the non-legume, in their mutual action.

In an experiment with maize interplanted with the legume (*Crotalaria anagyroides*) reported by J. G. Osserwarde, Netherlands East Indies (page T. 19, *Int. Rev. of Agr.* Vol. 27, 1936) in two out of three cases the yield of maize in the combination was about the same as in the pure maize crop and in a third case was very much reduced amounting to less than about one half of the yield on the pure maize plot.

Another experiment reported is from V. C. Calma and J. P. Tiangsing and relates to the growing of a catch crop of peanuts and soyabeans along with sugarcane. The planting of the sugarcane and the sowing of the catch crops were done at the same time, and the latter were sown between the rows of sugarcane and also in the space between one set and another, the sets themselves being planted 50 cm. apart and the rows one metre apart. Both the peanuts and the soyabeans were harvested and removed when they matured. The effect of the catch crops was found to be detrimental to the sugarcane in many ways. The germination of the cane was only 75·4 per cent in the peanuts plot, 79·3 per cent in the soyabean plot, as against 88·9 per cent in the control and 93·5 per cent in the ammonium sulphate manured plot. The growth of the cane plants in the intercropped plots was stunted, the number of millable canes was also reduced and the final yield of cane also suffered seriously. The following were the yields of sugarcane in the different plots:

Table II

Yields of sugarcane

Plot	Yield of sugarcane
Control plot	68 tons per hectare
Pea nut plot	58·5 „ „ „
Soya beans plot	62·7 „ „ „
Ammonium sulphate manured plot	78·0 „ „ „

(*Philippine Agriculturist*, June 1940)

We shall revert to this experiment in the next heading, with reference to certain other features, but here the relevant point is that the association with legume in this particular manner was seriously harmful to the main crop of sugarcane.

Is there an increase in the nitrogen percentage of the grain or stems and leaves of the cereal in mixture than in pure cropping? From Nicol's review of this part of the subject it would appear that the results of work on this aspect of the question have not been consistent one way or another. Westgate and Oakley found the percentage of nitrogen in wheat was slightly reduced, Lipman states that the presence of a legume does not always result in an increased proportion of nitrogen in the dry matter of the non-legume, and the former authors make the same observation. Experiments by Vatiovaara [1933] also showed a lowering of the nitrogen content in the ripe oat straw when grown in mixture with peas than when grown pure. Pilz's work [1911] with barley, maize, and oats grown pure and in mixture with legumes, showed that in the pure crops barley and maize contained a higher percentage of nitrogen than in the mixed cropping, but that in the case of the oats the contrary was the case.

In reply to a circular letter addressed to all Agricultural Chemists in India inquiring if any work on this subject had been carried out by them, the Agricultural Chemist in Coimbatore has written to say that in a field experiment conducted by him on mixed cropping using *Chitharai cholam* (Summer *cholum, Sorghum vulgare*) as the grain crop and (1) greengram (*Phaseolus radiatus*, Linn.) (2) Cluster beans (*Cyamopsis psoroloides, Dc.*) (3) red gram (*Cajanus indicus*, Spreng) and sannhemp (*Crotolaria juncea*, Linn.) as the leguminous crops, it was seen that the protein content of the grain was increased when grown in mixture with these legumes, that the average increase in protein was about 26 per cent and that the highest increase was 34 per cent which was obtained when the grain and legume were grown in equal proportion (The work has not been published yet).

In alfalfa-grass mixtures, not only do the mixtures out yield pure grass (sometimes even leaving out the alfalfa out of consideration) but the protein content of the grass is definitely higher than in the pure grown grass, viz., an average of 44 per cent for *Dactylis glomerata* and 50 per cent higher for timothy (*Nicol's review*). In reference to such mixtures the following remark by Nicol appears on the whole to be worthy of acceptance, 'provided that these (phosphate and potash) are given and that the proper nodule bacteria are present in abundance, it appears that a mixed crop is able at least to supplement the soil's nitrogen to a degree sufficient for the growth requirements of both grasses and legumes. Mixed cropping in fact seems to present us with the opportunity of gatherig nitrogen through phosphorus.

Finally, we may refer to the work of Anna Nowotnowna (*reported in Jour. Agric. Sci.* 27, 503—510) because they relate to all the experiments considered so far. These experiments relate to mixtures of the cereals and legumes, barley, rye, peas, red clover, serradella, and lucerne grown in nitrogen free (but inoculated) sand cultures. The results showed, rye grass increased in yield of total dry matter and nitrogen content in association with the legumes ; thus in respect of dry matter, with peas it was three times, with clover twice, and nearly twice with serradella as compared with rye grass alone. In respect of nitrogen content, rye grass with peas contained five times, with clover three times and with serradella twice as much total nitrogen as it did in pure culture of similar age. Among the legumes, peas were found the best companion for rye and serradella came last. As regards barley, neither red clover nor lucerne had any favourable effect on the barley and only peas exerted such action in respect of dry matter, total nitrogen and nitrogen percentage.

The reason suggested as probable for the barley not benefitting by red clover and lucerne is interesting and noteworthy and deserves to be remembered in connection with cereal legume mixtures in general. The suggestion is that the period of vigorous nitrogen fixation by clover and lucerne coincided with the ripening stage of barley, when its assimilation was over and it was unable to utilise nitrogen, so that an additional factor, viz., the growth period of the crops concerned is introduced, which has to be reckoned with both in planning the experiments and interpreting the results.

How does the non-legume in the mixture benefit by association with the legume? Virtanen and his associates have concluded that root nodules exude nitrogen compounds in the shape of amino-acids (which constitute almost 99 per cent) ; the

utilisation of these compounds by associated non-legumes may vary in degree, which may account for the fact that the benefit to the non-legume is not always the same ; that non-legumes may vary in their ability to take up or utilise these exudates, and that the legumes themselves can differ in their capacity to exude have given rise to ideas which are expressed by the very apt terms 'donors and donees of nitrogen' and that the benefit can accrue only when the donor legume is associated with the proper and appropriate donee. The terms 'compatible and incompatible' are also used, all of which are of course only descriptive and by no means explanatory. On this basis taking into consideration the large number of legumes and non-legumes among the agricultural crops of India the possible combinations to be investigated becomes almost unlimited, even allowing for the fact that agronomic considerations may restrict the number considerably.

How does the varying of the ratios of legume to non legume affect the growth of the other? In most of the work reviewed by Nicol and reported by others, observations have been made of the effect of varying the ratios between the legume and non-legume in the mixture sown. Virtanen and his associates investigated the growth of the peas and oats in the ratios of 1, 2, 2·75, 4 and 5 oat plants per pea. It was found that if the ratio of non-legume to the legume approached or exceeded 2 : 1, then the growth of both species suffered and in the above experiment the setback to peas was most evident where the cereal was numerically preponderant. Oats and vetch mixtures in three different ratios showed significant differences in yield in experiments at Rothamstead, the yield of pure oats was the highest, and went down in the mixture as the proportion of the vetches increased. Likewise in older work also (Pilz) combinations in different ratios were studied. Madhok in his experiment referred to already found that in the chick pea wheat mixture, the grain formation in the wheat seems to suffer when the ratio of chick peas to wheat is 1 : 4, and that the efficiency (relative) of the nitrogen fixation appears greatest when the ratio of chick pea to wheat is 1 : 2. We have already referred to the Coimbatore experiment where the protein content of the grain was highest when the proportion of the legume to non-legume in the mixture was 1 : 1.

Before leaving this subject, attention may be drawn to the following remark made by Nicol, as it has an important bearing upon the interpretation of all experiments on mixed cropping : 'There are evident difficulties regarding the way in which yield of single components may be compared in pure cultures and in mixture. These difficulties have been discussed at some length by Pilz [1911] ; the safest method of comparison would seem to be that used by him, whereby in a mixture of one legume and one non-legume sown at approximately equal rates, the yield of the non-legume in mixture is compared with that of the same non-legume grown in pure culture upon half the area occupied by the mixture. The basis may be said to be one of ground utilisation'. It is not known whether in all the works reviewed, the yields were calculated upon this or any other basis ; at least one was not, and in this case Nicol comes to a directly opposite conclusion to that arrived at by the author viz., Lyon in his experiment on maize—soya bean mixture. It is not unlikely

that looked at in this way other results may be capable of a different interpretation from the ones reported. In any case it is evident that in addition to the inconclusiveness of the results a new and material disturbing factor is introduced in this way which tends further to make the results far from conclusive.

Legumes and soil enrichment in nitrogen. That the growing of leguminous crops greatly enriches the soil in nitrogen by the action of the nitrogen fixing bacteria in their root nodules and that such enrichment is greatly to the benefit of the succeeding crop is perhaps too well known and too well established to require any special mention, unless it be to emphasise what is perhaps not so well known viz., that they can do so only when the soil is well provided with the other plant foods, phosphoric acid and potash, it has the necessary content of lime and that above all it is amply well stocked with the appropriate root nodule bacteria. No reference needs to be made either to the classical experiments on the subject or to the large mass of subsequent work. A measure of such increase in nitrogen is brought out in a well known Rothamstead experiment where a crop of barley following clover contained nearly twice the quantity of nitrogen that was contained in barley which followed a crop of barley. As Sir John Russell observes ' these facts are well known to the practical man and are utilised for increasing the nitrogen supply of cultivated soils and for reclaiming barren sands and clays, (*Soil Conditions and Plant Growth*, page 353). Much work has been done to determine not only the extent of the residual effect of legumes in the above manner but also the length of time that it lasts, the causes that may lead to its reduction and the ways of preventing losses, but such work has been confined to the conditions of Europe or America. As far as the tropical conditions are concerned and especially Indian conditions, similar work is a great desideratum. What is the extent of the increase in nitrogen with different or common Indian legumes ? How deep does it extend ? How does the long spell of the Indian hot weather following harvest affect the quantity, condition and location of the added store of nitrogen ? Likewise how do early rains with the help of which ploughing and other preparatory cultivation is carried out affect these ? these are all important questions which will influence the practical application of this property of legumes under Indian conditions but on which little scientific investigation has been carried out and no reliable information is therefore available.

The conclusions which may be drawn from this review of this particular aspect of mixed cropping is that the subject requires to be investigated thoroughly, both in respect of fundamentals in the laboratory and the pot culture house and as applied to field experiments, and that the scope for such work is almost unlimited. The results of the work so far are quite inconclusive; there is as much to be said in favour of the legume—non-legume association as mixed crops, as against it; indeed it even looks as though the results against such cropping preponderate.

Mixed cropping and soil moisture relationships

Where a particular crop has to be planted or sown in rows fairly wide apart, because the plants have a bushy habit of growth and when full grown their tops and branches will meet at some height above ground, or because their habit is that

of a bushy creeper, and when fully grown they meet and cover up the surface of the ground, is it better to grow a crop between the rows which can be harvested and removed by the time the rows close up or to keep the spaces free of crop but well stirred and worked by light hoes, or even leave them quite untouched ? For instance, should cotton be grown by itself sufficiently wide apart for good growth, the space between the rows being cultivated clean or is it permissible to grow a mixed crop of say, Italian millet (as is very often the practice) in rows or coriander broadcast (as is common in some places) ? Or in permanent crops like coffee, tea, rubber, or cocoanuts, should the ground between the trees or bushes be kept clean and tilled, or is it permissible to grow some crop, if it is possible to do so, for the sake of its produce or as a mere cover or green manure crop ? It is true that in practice only economic considerations will decide the choice, that is to say, that practice will be adopted which yields the greatest return after deducting all expenses. Among the factors that from a scientific study can be said to influence or underlie such practices, the question of soil moisture as affected by one or other of these methods becomes a very important one. In tracts where the rainfall during the growing period is abundant or sufficient or where crops are grown under irrigation, the question is not very important but in dry cultivation and especially where the rainfall is neither ample nor certain and in the case of the *rabi* crops which are grown after the rains are almost over, all the factors which may influence the quantity of soil moisture assume importance and have to be studied. Since the bulk of mixed cropping relates to dry cultivation the methods of conserving soil moisture so as to offset the shortage or vagaries of the rainfall deserve detailed study. Is mixed cropping helpful in this respect or is it harmful ? During the discussions on mixed cropping this subject was referred to by Dr Carpenter, particularly with reference to practices in tea estates; but it has even greater importance in connection with the ordinary annual field crops.

To what extent and to what depths do these inter crops like Italian millet for instance in the midst of cotton or the so-called cover crops and green manure crops deplete the soil moisture ? And on the contrary to what extent do they protect the soil surface by preventing evaporation ? Certain experiments in Mysore have shown that the drying effect of these crops is very great ; in tests of the comparative effects of various treatments viz., soil uncultivated, soil stirred upto 1½ inches, soil dug 1½ feet and soil growing Bengal gram, it was found that even a small crop of Bengal gram (*Cicer arietinum*) drew upon the soil moisture to a depth of 6 feet and that this ' difference in moisture between the gram plot to a depth of 6 feet and the uncultivated plot would have been compensated for by an application of 3 inches of water over the entire plot; and between it and the plot cultivated 1½ inches depth by an application about 5½ inches of water. It will be necessary to conduct similar tests with other crops, so as to decide the extent of such drying effect and to what depths this may extend, with reference to the root range of the different crops. If during the growing period of the crops there is not sufficient rainfall to offset this loss of moisture it is obvious that both the main and the mixed crop would suffer. What applies to the mixed crop applies also to the moisture depleting effect of the weeds which may spring up and grow if they are not removed as they appear. All work

done so far on this subject may be taken to have established definitely such drying effect. If this should be so, then the growing of these mixed crops is detrimental; and the need is all for measures for checking such effects, either by thorough removal as in the case of weeds or other methods, which will have the effect of conserving soil moisture, by establishing soil or other mulches or by shade.

(The question of conservation of moisture by preventing surface wash, by methods to impound rain water or make the soil absorb or retain it more thoroughly and so on, all of which are essential features of dry farming are being left out of consideration, as they all relate to the period when no crop is standing on the field). The mulches are formed by either soil mulches or are provided by the thick layer of fallen leaves in estates, the leafy loppings of young branches of shade trees and plants, the prunings of tea bushes as in tea estates, or by even special materials like dry grass brought in and applied for the purpose. The soil mulch in the case of the ordinary field crops is provided by interculturing by the different kinds of bullock drawn implements or by hand tools or by both. This kind of inter-tillage stirs the surface soil to not more than two or three inches and it is a question for consideration whether such a mulch affords any protection at all and if so, whether it is large enough to justify its being carried out frequently. Mysore experiments already referred to showed that even a mulch of $1\frac{1}{2}$ inches provided some protection but it was too small to be considered responsible for any increased growth (Dr Lehmann, *Annual Report of the Agricultural Chemist* in Mysore for the year 1906—1907, pp. 29, 30). This very small saving in moisture can hardly justify the importance commonly claimed for the practice and the labour required. The operation however has to be carried out, in order to get rid of the weeds and to prevent the loss of soil moisture through that cause, and in view of its importance in this respect can under no circumstances be neglected or omitted. It will be difficult to assess the value of the cultivation separately as between its soil mulch value and its weed control value. Its importance in this respect may be judged by the practice of hoeing more than once, the bullock hoeing being followed later by a hand hoeing, so that the weeds may be removed as they come up. The question whether it may be dispensed with in view of the very small saving of the soil moisture gained has no practical bearing; except perhaps to stress the fact that once weeds have been got rid of there is no further need to intercultivate even though the rows may not have closed in and interculturing may be possible. This in fact is the conclusion arrived at as the result of experiments in Rothamstead on the value of intercultivation, viz., ' the net result of all this work is to show that, provided the crop has a reasonably fair seedbed, that it is given a hoeing in its early stage and that the worst of the later weeds kept down, then any cultivation in excess of this minimum is of little direct value to the plant. In practice this minimum coincides with the number usually given.

While thus the presence of mixed crops makes it very difficult or impossible to carry out the interculture thoroughly which is so very necessary whether we look upon it as a weed control measure or a moisture conserving expedient, it has in addition been found a most serious obstacle in carrying out the ploughing of the field immediately after the main crop is harvested and before the soil begins to dry.

Such ploughing has been found to be a most beneficial dry farming practice, judged by its effect on crop yields. In experiments conducted by the Mysore Agricultural Department the value of this practice has been fully demonstrated as may be seen from the results extracted below :

TABLE III

Yield of grain ragi (Eleusine coracana) *in lb. per acre*

—	1909	1910	1911	1912	1913	1914	Average six years
Autumn ploughed	940	755	755	642	557	900	950
Ploughed shortly before sowing (in regular season)	640	445	235	315	281	375	382

(The Cultivation of *ragi* by Leslie C. Coleman page 8)

' It cannot be definitely stated whether this striking effect is due to any moisture conserving action of the ploughing ; indeed the indications are that the saving in moisture is too small to account even partially for such a large result '.

The whole conception of capillary rise of water in the soil, its rate, and the effect of a loose soil mulch as against a hardened surface has undergone change and the possibility of changes taking place as a result of the condition of the surface soil is questioned. It is perhaps even correct to believe that the hard surface soil, far from helping the sub-soil moisture to rise and be evaporated from the surface, itself forms an effective seal and prevents any such rise. In one of the numerous soil moisture determinations made by the author a curious case has come across which is worth noting in this connection. In a spot where the sub-soil water (the water table in fact) was only about 18 inches below the surface, the top soil in the hot weather was so hard and dry that the soil augur had difficulty in penetrating through it. The percentage of moisture in successive 3 inches sections of the soil proceeding from top downwards was as shown below : 3·6 per cent, 6·3 per cent, 10·6 per cent, 13·6 per cent, 14·3 per cent and 14·8 per cent at which level viz., 18 inches below ground the water table was reached. Moisture determinations were again made a month later and the results were found to be of the same order, so that even though the sub-soil was soaking wet with standing water at a depth of only 18 inches the top soil was dry and hard, (Dr A. Lehmann, *Annual report of the Agricultural Chemist in Mysore, vide* page 25-27, VIII). As has now been established an ' important practical consequence of the hysteresis is that the water in the soil tends to resist change, whether these are in the direction of increasing or decreasing the moisture content. Instead of moving through the pores from regions of high moisture content to low it will adapt itself to the suction gradient mainly by an alteration in the

configurations and curvature of the water films. To use an expressive Americanism, the water 'stays put if it can' (B. A. Keen, Physical Research and Problems of Soil Cultivation, in '*Endeavour*' April, 1942). The observations made by Dr Coleman in reference to the results of the experiments described above are worthy of note. He states 'the results can leave no doubt as to the immense importance of getting the land ploughed as early as possible. What factors are concerned in producing this great difference will have to remain as a subject for future investigation.'

Attention may also be drawn to the cultural practices which are adopted in the cocoanut gardens of the Mysore State which are grown in dry fields solely with a rainfall which does not exceed 25 inches in the year. It is a settled routine in these gardens to plough them six times in the year, thrice in the early rains and thrice late in the year after the rains of the year have ceased, in the belief that these are helpful in enabling the soil first to absorb as much water as possible and then to retain as much of it as possible. All permanent gardens of fruit and other trees are also invariably given a good digging after the rains are over from the month of October onwards in the same belief. If water conservation is not a factor or is not a chief factor in producing the beneficial results for which these tillage operations are adopted, then what other factors, such as bacterial action, greater aeration and weathering etc. may be responsible will have to be examined. The point to emphasise in this connection is that these forms of tillage are of undoubted benefit and that the system of mixed cropping offers in practice a serious obstacle and is therefore a hindrance in carrying them out.

We may now refer to what may be called the protective effect of the mixed crops which may be put down in favour of the system. In the first place the shade afforded by the crop whether main or mixed has been found very beneficial. On tea estates a mixed crop of *Tephrosia candida* grown as a nurse crop or ~~as a~~ green manure crop between the rows of the tea bushes has been of remarkable benefit in this respect. Dr Carpenter of the Toclai Research Station, writes, 'when I visited Ranchi at the end of May where and when drought conditions are very severe, tea growing in the open on clean land having a soil mulch was dying down to the soil level, whereas tea growing under the shade of a growth of *Tephrosia candida* showed vigorous growth and was not dying back. It might have been expected that the large growth of *Tephrosia candida* of the soil might have resulted in the soil becoming more depleted of moisture than land which is kept clean of extraneous plant but this did not seem to be the case as judged by the growth of the tea' (Dr Carpenter's letter to the author). In fact both in tea and coffee cultivation it is now held more or less as a general belief that (apart from the question of shade trees) it is the best to have the bushes themselves shade the ground as completely as may be consistent with the need for the free movement of the coolies and that the shade of the bushes and the mulch of the fallen leaves will conserve moisture to such an extent that forking, digging or such disturbance of the soil for the production of a soil mulch can be dispensed with. Reference may be made in this connection to the excellence of what used to be called the 'Leeming system' of coffee growing, the distinctive feature of which was this method of shading, the ground. It is also worth noting

that the idea that tea did not require shade has now changed and shade trees are now becoming a feature in many tea estates.

In ordinary field crops also the protective effect of the crop rows whether of the main crops or of the mixed crops by shading the ground, by reducing evaporation, by breaking the velocity of the wind and the consequent rapidity of drying and by lowering the temperature near the surface of the ground, has to be noted in favour of the growing of mixed crops, as against leaving the interspaces bare of crop. Considerable work on this aspect of the subject has been done by the Agricultural Meteorologist in Poona to which reference may be made here. The temperature of the air near the ground level inside crops is much lower than in the same level in open uncropped land, the difference in the case of a sugarcane crop being very marked, viz., 14° at ground level, 5·5° at 2 feet and 3° at 3 feet height above ground. In the case of a *jowar* crop also the temperature inside the crop at ground level was much lower than in the open. There is also a tendency for the vapour pressure to decrease rapidly with height in cropped land, and the moisture content of the atmosphere inside crop is higher at all heights than in the open (R. J. Kalamkar, *Cur. Sc.* Vol. III, No. 2, August 1934, pp. 80—81). The evaporation of moisture from free water surface is found to be influenced more by the movement of the wind than by soil temperature itself; thus, upto a height of 4 feet, evaporation was found to increase with height above ground level, even during the afternoons when the ground temperature was the greatest. Wind velocity is broken and very much reduced by crops thus leading to a reduced evaporation of surface moisture inside crops. Inside a crop of *jowar*, at a height near the ground level the velocity was 35 per cent and at a height of 6 feet it was 80 per cent of the velocity out in the open uncropped land. Similarly in the case of a cotton crop at heights between 1 and 3 ft. it was cut down by 70 per cent, and in sugarcane it was 60 per cent at ground level and 90 per cent at 8 feet (P. K. Raman, *Indian J. agric. Sci.*, Vol.XIII, Part III, pp. 273—275). It is thus seen that the presence of a crop on the ground tends to conserve the moisture of the soil at and near ground level, as against leaving the ground bare which has the contrary effect. It may also be expected that a crop on the land tends to break the force of the rain and to check any rapid flow of the rain water from over the surface and thereby help the soil to absorb a greater amount of the rainfall than the bare open uncropped land. The addition of moisture during dewy nights is probably more on cropped land than in the open, on account of the larger condensation of the moisture on the plants than on the surface of the ground, though this fact is not well established. All these factors should be considered to weigh greatly in favour of a good crop cover as is implied in mixed cropping, from the point of view of conserving moisture on the surface soil.

Side by side with such conservation of moisture, there is the loss due to transpiration going on in the case of the cropped land, which draws upon and reduces the soil moisture upto varying depths at and below the root range of the crops. Root studies show a surprisingly deep root system even for crops usually considered shallow rooted. Thus wheat, oats and sugar beet send down roots upto 6 feet, barley to about 3 to 4 feet, and potatoes upto 3 feet (B. A. Keen). The depletion of soil moisture due to the presence of mixed crops should therefore extend to at least

these depths. These losses and gains to the soil moisture due to the presence of a mixed crop have therefore to be weighed against each other, and a balance struck, before we can assess the value of mixed cropping. One other factor to be considered with reference to this aspect of the subject, is the extent in width and depth of the root range of the crops employed in mixed cropping. If both the main and the mixed crop have the same depth and area of feeding roots, the effect of the mixed crop cannot but be detrimental to the main crop, other things being equal. On the other hand, if the range of the feeding roots of the one crop is much deeper than that of the other then they may be more compatible, and the harm to either may not be great. Root studies of some important crops have been in progress in India to some extent, for elucidating many factors of crop production, and it will be very desirable that the studies should relate to more crops and with reference to the problem of mixed cropping, so that we may have more knowledge as to what mixtures are suitable and what are not. This as a matter of fact forms part of the recommendations made at the conferencce. The subject of root depth in relation to the uptake of plant foods from the soil is dealt with in a separate section.

Mixed cropping and nitrification

It is sometimes claimed in favour of mixed cropping and the shade and humidity referred to above, that under these conditions nitrification proceeds more rapidly. Thus Dr J. A. Voelcer says ' It is known also that the process of nitrification in soils is much more active when a growing crop is on the ground than when the latter lies fallow ' (*Improvement of Indian Agriculture*, page 234). Later work does not lend any support to this view. While it is true that bacterial activity is greater in cropped land than in the fallow, it appears to be fairly well-established that such activity does not relate to nitrification. On the other hand it has been found that ' the total amount of nitrate present in cropped soils is less than that in adjoining fallow soils even when allowance is made for the quantity absorbed by the plant. This fact has been observed at Rothamstead, at Grignon, at Ithaca, in Europe, India and Egypt '. (Sir John Russell, *Soil Conditions and Plant Growth*, page 509) Indeed it has been suggested that some crops interfere with nitrate accumulation. ' It is thus seen that the view that mixed cropping is favourable to nitrification is not correct. Work on the nitrogen fixation Capacity of black cotton soils in the Central Provinces also brings out the fact that the Capacity 5 higher in fallow soil than in similer soil taken from adjoining cropped fields (D. V. Pal, *Proc. Nat. Inst. of Sc. Ind.* Vol. III, No. 2).

Mixed cropping in relation to the utilisation of plant foods

It may be claimed in favour of mixed cropping that under this system the resources of the soil in regard to plant foods naturally present in it or added in the shape of manure are utilised to a fuller extent than will be the case when only a single crop is grown. This result may follow from the facts (1) that the roots of the different crops are of varying depths, such as those of shallow rooted crops and of deep rooted crops and (2) crops vary in the quantities of the different plant foods required or removed by them from the soil. That deep rooted crops can take up plant foods from greater depths as their roots traverse and can forage in the deeper layers of the soil is almost self-evident. Experimental proof is however available

in one of the early experiments in agricultural research, viz., one by Eckenbrecher quoted by Storer. Eckenbrecher arranged an experiment with oats and lupines in such a manner that nitrogen in the form of nitrates could be available or accessible to the roots only at a great depth and not near the surface. The oats in the experiment made only a poor growth, as the roots were confined to the layer of the soil near the top but the lupines made a vigorous growth and their roots had reached down to the layer where the nitrate was buried, (*Storer's Chemistry as applied to Agriculture*, Vol. III, page 54). As the mixture of crops usually found in mixed cropping consists generally of a shallow rooted crop such as a cereal grain like rice, *ragi*, *jowar*, Italian millets, etc., with a deep rooted crop like redgram, cotton, field beans, etc., both the upper and the lower deeper layers of the soil are drawn upon by the crops and utilised in the crop season. From this point of view it is necessary or advisable that the crops selected for mixed cropping should consist of these two different types and not plants of only one type, such as either shallow rooted crops alone or deep rooted crops alone. There is no definite information available regarding the depths which are usually traversed by the different field crops in India, in the different principal soil types, such as the light Gangetic alluvium, the black cotton soils, and the red (lateritic) type of soil of South India. Great and striking differences are likely to exist in these different soils and in respect of the different crops the depths considered usual in one type may be far exceeded in others. During a visit to the Sugarcane Research Station at Shahjahanpur by the author it was seen that a cane clump whose root depth was being examined had a root depth which was very much more than anything seen in the soils of Mysore. There can be no doubt that the depths attained in this (Shahjahanpur) type of soils by the different crops will be found to be greater than on South Indian soils, and perhaps in the black cotton soils. In the latter too the fact that these soils vary very much in depth and are underlaid by rocks in varying degrees of disintegration or hardness at different depths below the soil may cause further differences in the root depths of crops. In one and the same type of soil however the depths of roots relatively to each other are likely to be the same as in another type and their comparative rank or position may not be affected.

Reference may be made to the studies of the depths of roots in the various new varieties of sugarcane at the Imperial Sugarcane Research Station at Coimbatore. These reveal very striking differences in the depth, number and manner of develop, ment of the roots and these have been found to correspond to important differences in the robustness of growth of the particular varieties as compared with one another. As a result of such differences the varieties presumably differ in the amount of water and plant food they are able to take from the soil. It is greatly to be desired that both from this point of view and from the point of view of the utilisation of soil moisture, studies of the root depths should be systematically undertaken for all the principal field crops and in the three different soil tracts.

Root studies are also desirable in respect of irrigated cultivation, (especially in the Punjab where much mixed cropping is practised under irrigated cultivation) as there is no doubt that under this condition material differenecs may be brought about in the depth and range of the roots. Such differences may arise even under

normal irrigation and soils, but under conditions of a high water table and of salt accumulation and so on, which frequently accompany irrigation in a flat country difficult of drainage, unexpected differences are likely to be found in the character of the root system.

A fuller utilisation of the plant food resources is also made possible because crops seem to possess inherent peculiarities in taking up some plant food elements more largely than others although this is by no means an indication of what they will respond to most when applied as manure. Crops differ not only in the quantities of plant foods each of them remove but also in the proportion in which these are taken. There is no doubt that crops do exercise some kind of selective action in regard to these plant food elements or differ in their 'feeding powers' as it is sometimes termed. As far as can be seen, no figures seem to have been worked out for the total quantities of the different plant foods which are removed from the soil by the above ground parts (including leaves, stems, straw, grain, chaff, pods, husks, etc.) of the field crops of India, under average cropping conditions except in a very few cases. As such figures are however available for European and American crops these are extracted in Table IV in order to bring out the extent of such differences.

TABLE IV

Total quantities of plant foods removed by some important crops and the proportion in which they are removed

Serial number	Crop	P_2O_5 Quantity	Ratio	K_2O Quantity	Ratio	N Quantity	Ratio
1	Wheat	21	43	29	60	48	100
2	Barley	21	43	36	75	48	100
3	Oats	20	36	46	83	55	100
4	Beans	29	27	17	63	106	100
5	Potatoes	24	35	77	115	67	100

(Worked out in lb., per acre for a 30 bushel, 40 bushel, 45 bushel and 30 bushel crop of wheat, barley, oats and beans respectively, and for a 6 ton crop of potatoes, from Warington's figures given in *Soil Conditions and Plant Growth*, by Sir John Russell, page 507, sixth edition).

Taking the nitrogen as 100, it will be seen that the phosphoric acid varies from 27 to 43, the potash from 60 to 115 and the nitrogen itself from 48 to 106, as between the different crops. It is surmised that the secretions from roots or root sap differ in character from crop to crop and that some are able to dissolve out more phosphates than others, although what this acid may be whether merely carbonic or something more effective may be said to be not quite decided.

From practical experience relating to the response of different crops to various manures the theory of 'dominant ingredients' attributed to Ville draws attention to the same differential action exercised by crops in making use of plant foods in the soil or in the manure, whatever may be the mechanism by which such differences may be brought about. Under this classification (referring again to European crops) the cereals except maize come in the class for which nitrogen is the dominant constituent and the leguminous crops, potatoes and flax have potash as the dominant constituent. As for Indian crops, no such predeliction is noticeable, as the general experience with manuring shows that for nearly all the crops nitrogen is the most important and the most predominantly needed plant food, the others coming a long way behind, and often leading to no increase at all.

Reference may be made to the fact that the plant food elements are not at all made use of at the same time, but are taken up mainly or in large quantities at particular stages, in the growth of the crop and that this period in the growth is also different for different crops. An abundance of one or other of these plant foods at particular stages in the growth of the crop also appears to be favourable in particular respects. Nitrogen is taken up largely from the very outset by all crops. Nitrogen specially applied about the middle of the growing period in the case of the grain crops has been claimed to favour the increase of the protein content of the grain.

In regard to sugarcane a fact of some interest in this connection may be mentioned. It has been the general experience in India that although the sugarcane crop removes from the soil surprisingly large quantities of potash, there is little or no response to potash manuring ; on the other hand there have been experiments in which potash has resulted in a reduction in the yield. In all these cases the potash manure has been applied like any other manure at the early stages of the growth, say up to a period of three or four months, after which it is not usual to apply manures to the cane. At the Shahjahanpur Sugarcane Station the author was given to understand that the absorption of potash by sugarcane takes place largely in the later stages of the growth. Apart from showing that plants take up plant foods more largely at certain stages than at others, this fact affords a possible explanation of the observed results of potash manuring and a promising suggestion as to the lines both of future manurial experiments with potash for sugarcane and perhaps even for immediate practical application. The point however to be stressed in connection with the utilisation of plant foods is that crops may differ in the stages in which they may take up the plant foods as they do in respect of the quantities and proportions. It will be a very desirable line of research to determine for the main crops the particular periods of growth during which the maximum absorption of nitrogen, phosphoric acid and potash each takes place.

These three considerations viz., the difference in the depths of the roots of different crops, in their capacity of selective absorption of plant foods and in the growth period when maximum absorption takes place would appear to make mixed cropping a more efficient and balanced utilisation of the manurial resources of the soil in any particular crop season than the growing of single crops with or without rotation.

MIXED CROPPING AS A METHOD OF INSURANCE AGAINST LOSS

It is as a method of insurance against total crop failures that the system of mixed cropping finds its merit and justification in the opinion of all observers. Thus Dr Buchanan as long ago as a century and half writes 'the reason for sowing these plants (*Dolichos lab-lab* and *Cajanus indicus*) along with *ragi* (*Eleusine coracana*) seems to be, that the rains frequently fail and then the *ragi* dies altogether or at least the crop is very scanty; but in that case the leguminous plants resist the drought and are ripened by the dews which are strong in the autumn. When the *ragi* succeeds, the leguminous plants are oppressed by it and produce only the small return mentioned in the above list, but when the *ragi* fails they spread wonderfully and give a very considerable return, '(Dr Buchanan's *Travels in Mysore*, Vol. 1, page 101). R. G. Allen writes 'an examination of the fields will show that most sowings are mixed, partly to get the necessary variety, and partly it is true as a species of insurance against unfavourable weather conditions and as a method of providing the effects of crop rotation,' Allen R.G., *An Outline of Indian Agriculture*, page 25). 'Mixed cropping was based mainly on economic considerations. In the United Provinces it was an insurance against the inclemencies of the weather, pests and diseases'—Dr B. L. Sethi. 'Villagers would not give up the practice, as they were certain of getting good yields from one or other according to seasonal fluctuations',—Mr. S. Harachand Singh. ' It is generally accepted that mixed cropping is an insurance and also maintains soil fertility',—Dr B. N. Singh. 'Mixed cropping in Mysore has been practised as an insurance against the vagaries of nature and the precariousness of the rains', Director of Agriculture, Mysore. ' Mixed cropping as an insurance against bad weather and soil conditions is practised ', Director of Agriculture, Bhopal. 'The practice is adopted primarily to secure at least a small return under conditions in which pure sown crops would be total failures, in other words as an insurance against total failure of crops sown pure', Director of Agriculture, Madras. It was this feature of mixed cropping which accounts for the result described by one of the witnesses before the Royal Commsision on Agriculture (Rao Bahadur Govind Bhai Naib Dewan, Baroda). ' Some effort at separating the mixtures and making suitable rotations out of them was made but without any striking results of any importance '. Whether the system was designed deliberately with this aim in view or that it happens to serve this purpose among other advantages, there is no doubt that in the peculiar conditions of Indian agriculture, depending as it does very largely upon a rainfall the uncertainties of which are the only certainties in the country, this aspect of mixed cropping must be considered to be the most important. The need and the importance of this kind of insurance far outweighs the importance that may otherwise be attached to well established principles like crop rotations, keeping varieties pure, getting the maximum from every crop and so on, to all of which the system may in many respects be regarded as diametrically opposed. When it is remembered further that mixed cropping is adopted almost entirely only in the case of dryland crops which depend solely on the rains, as distinguished from irrigated crops, the need for such a form of insurance becomes even more evident.

We may now deal with some of the crop mixtures which illustrate this aspect of the system. The most important illustration which

is also perhaps the most general one seen throughout India is the mixing of the red gram crop with the grain crops usually grown in the respective tracts. In Mysore and many parts of Madras, with the food grain *ragi*, the *ragi* fieldbean mixture is another important illustration. Cotton with a grain crop, castor with a grain crop, castor with horsegram, the various *bajra* mixtures with groundnuts, pulses and oil seeds, in fact most of the large number of mixtures described in these pages, all illustrate this aspect of mixed cropping. In fact whenever two crops of different periods of maturity comprise the mixture, which applies to the largest number of mixed crops, this aspect may be said to be illustrated. Even with crops of the same duration, like wheat and gram, wheat and linseed, wheat and mustard, etc., differences in their ability to make use of soil moisture at different depths and of the heavy dews of the season help this insurance against loss.

While all these refer to the mixture of totally different crops, the case of the mixed crops where the mixture comprises different varieties, strains or species of the same crop, comes in a different class but illustrates the same principle. Separate reference has to be made to this special type of mixed cropping in which there is only one particular crop grown but in which the mixture arises from the fact that two or more varieties of it are grown together, the seeds being mixed and sown. The question has an important bearing upon the practical value and application of the vast amount of work in progress in the isolation, testing, multiplication of improved varieties and strains and the recommendation that these should be grown pure in preference to a promiscuous mixture of strains and varieties. The object in growing only pure strains relates both to the quality and the quantity or yield of the produce and also to the need and advantage from a commercial point of view of a single pure type of the produce. The importance of purity in varieties which possess marked differentiating characters, such as the most obvious one of colour or others less striking to the eye but equally marked like cooking quality, malting quality, suitability for different purposes, etc., or spinning quality in cotton, oil content etc., hardly needs to be pointed out; but the matter concerns in addition the growing of mixed strains in the same variety, where the question of quality does not arise. In the former case one would expect that under no circumstances can a mixture be justified or approved. Instances are however reported which show that such mixtures are not only prevelant but are also found advantageous and that therefore there is something to be said in their favour, which may justify approval of the practice if not a recommendation for their extension. It is the experience in Mysore that the growing of two or more strains or varieties of *ragi* in preference to a single pure strain or variety even if the latter is a high yield in special selection, like the H-40, or H-22 proves better under certain special circumstances than growing the pure strain. The H-22 requires a higher rainfall specially towards the end of the year, this condition obtains only in the Eastern districts generally, whereas the H-40 is not so, with the result that if a mixture is sown as ryots very often do, then a good crop is obtained, whether the rains are early or late. According to the tract and its rainfall, it happens that either the one or the other or a mixture of both scores. In fact the ryots' disinclination to sow pure crop strains is generally based upon the belief that over a long series of years a

mixture is found safer than pure one. Even in parts of England ' increased yield from a mixture of varieties is stoutly alleged by advocates of the practice' (F. C. Engledow and Ramiah). It may be recalled also that in the early years of wheat improvement in England by Prof Biffen a rather spirited controversy went on regarding the merits of a pure strain as against the sowing of mixed strains, the superiority of the latter being advocated by Dr William Saunders of the Canadian Department of Agriculture (apparently for the conditions of his province).

Some support is lent to the apparent superiority of mixtures over pure crops in certain experiments by Engledow and Ramiah (reported in *Jour. Agria. Sci.*, Vol. XX, 1930). In this paper the somewhat novel idea is mooted that such mixing leads to intensive competition under the stress of which both development and yield are favoured. Mr Ramiah writes to say that end rows in varietal test plots show a marked increase in development over those inside the plot and that such development cannot be put down to the larger amount of space which these rows enjoy. If this important finding should prove quite correct and generally applicable then a very strong case may be said to be made out in favour of mixing crops. The subject has such an important bearing upon the work of plant improvement and recommendations for the sowing of improved varieties that it deserves to be investigated further.

The most interesting example of this kind is the growing together of two distinct species of cotton, viz., *G. hirsutum* and *G. herbaceum* in mixture, contrary to the emphasis that has always been laid on the growing of cotton pure and quite contrary even to the legislative enactments like the Cotton Transport Act and the Cotton Ginning and Pressing Act all of which are aimed at the prevention of mixtures. It is reported that in the Punjab both local *G. hirsutum* cotton and American Cotton are grown together and that this yields a better crop than pure crops of one or the other. It is not stated whether the cotton of the two varieties is picked separately or together. It is reported from Indore (K. Ramiah) that the practice in the Indore plateau is to grow likewise a mixture of these cottons, that they are both picked together and sold by growers and that in the gins and godowns of the dealers the two are separated, and sorted out from the mixed *kappas*. It should certainly cost a fair amount of money to effect such sorting and the merchant will no doubt pass it on to the grower, who must therefore be obtaining a lower price for the mixture than for pure *kappas*. It is reported that the yield of the cotton from the mixture is greater than from a pure crop of either and further more that losses due to seasonal conditions are largely avoided. Other advantages are also noted viz., that the mixed cotton is of a higher quality, that the incidence of disease is less and so on. But it is not difficult to realise that what really decides the cultivators' preference for the mixture is this particular insurance against loss, which so successfully dodges the drought.

As against these observations, attention may be drawn to certain experiments in Mysore, in which the results of sowing pure strains of *ragi* were compared with those of sowing mixed strains. These experiments relate to three strains of pure

ragi, and were carried out over a period of two years. The results are shown in Table V.

TABLE V

Yield of grain in lb. per acre

Type	1914		1915	
	Pure	Mixed	Pure	Mixed
1	2485	1941	1093	583
2	2220	1690	1125	1083
3	2160	1536	1750	1210

With reference to the above results, Dr Coleman remarks 'The belief is fairly common in Mysore that mixtures are grown because the cultivator has found them to yield more than any of the pure types if grown separately. The few experiments we have carried out do not in any way support this view. In fact the pure types have, in cases experimented upon, give a higher yield than the original mixtures from which they were isolated, and in some cases the differences have been very marked '. It is of course arguable that the experiments relate to only two years, whereas the ryots' belief is based upon the experience of many years.

The insurance against pests and diseases when crops or varieties are sown mixed is also an important aspect, especially when we remember that the pests and diseases are so many and so destructive and that satisfactory remedial measures are so few. The insurance afforded by mixtures in respect of wilts and rusts especially is worthy of special notice. As regards insect pests perhaps the best illustration is the castor semi-looper pest which defoliates the crop so badly, leaving only bare stems that field has to be ploughed up and sown to another crop if the season would permit it. A mixed crop of horsegram or groundnuts when grown as a mixture in between castor rows as is often done, serves as an effective insurance, as they yield a crop and a money return although the castor may be a complete failure. This subject is dealt with in the next heading.

A case of mixed planting of two varieties of sugarcane with the object apparently of affording mutual protection is reported from the Argentine where the experimental interplanting related to the varieties POJ 213 and POJ 36. (*International Sugar Journal*, Vol. 37, 1933.) The following summary of this experiment has been kindly furnished by Mr Nanda Lal Dutta, Government Sugarcane Expert, Coimbatore. ' In Argentine POJ 213 which lodges very badly and POJ 36 which has an erect habit were mixed and planted in alternate rows and also in the same row. When planted in alternate rows POJ 213 lodged and POJ 36 always gave larger yields. In the mixed plantings which were continued to the sixth ratoon crop the two varieties existed together without either tending to gain ascendency over the other, either in number or weight of stalks or sugar content'.

MIXED CROPPING IN RELATION TO INSECT PESTS AND DISEASES

Both in respect of insect pests and fungus and other plant diseases their incidence and spread are held to be greatly promoted by the removal of the mixed natural vegetation in any region and its replacement by large stretches of single crops; as is brought about in the cultivation of field crops or by large plantations. The mixing of crops so common in India, says Dr Butler, 'has its advantages from this point of view, for a field of say, wheat, barley, gram, linseed and peas mingled together will probably suffer less from parasites than five separate plots of these plants', (*Fungi and Plant diseases*, page 107). It seems quite reasonable to suppose that if one or more rows of a crop which are not attacked by a particular disease or pest are interposed as a mixed crop in among another which is subject to attacks by that pest or disease then it can to some extent prevent the spread of the pest or disease across the field and thereby keep it in check and reduce the damage. This kind of beneficial effect can of course be secured only if the mixed crop is of such a kind that it is not susceptible to the particular pest or disease; in other words it will apply only in the case of particular combinations and not others. To what extent therefore this advantage may be expected in respect of the commonly practised mixtures and with reference to what particular pests or diseases is a point of great practical importance. It is also possible that some crops may have a repellent effect upon certain pests, which may therefore be grown as a mixed or a border crop to keep out the pest from the main crop which may otherwise be attacked and damaged. It is not known if there are any such among the ordinary crops and to what extent they can act as a protective crop. Bitter leaved plants, or those with strong smells like fenugreek and coriander respectively are sometimes mentioned by kitchen gardeners but it is doubtful if there is any truth in the belief. In any case, the belief does exist and it may be useful to obtain more information on this interesting subject.

It is also believed that some crops serve as a 'Trap crops', which will draw the attack to themselves and thereby protect the main crop from the attack by the same pest. The crop *bhendi* (*Hibiscus esculentis*) in the midst of cotton is reputed to possess this quality with reference to the cotton boll weevil, and its use as a mixed crop in cotton was at one time recommended for this reason. It is now found however to be quite useless and indeed according to Dr K. A. Rahman, to be harmful because it increases the damage rather than reducing it. Furthermore it mainly attracts only one species of boll worm viz., *Erias fabias* out of the three Erias. In regard to the supposed use of a windbreak or border crop of sugarcane to reduce damage by the white fly, Dr Rahman says that the border crop of cotton near sugarcane was vastly more attacked and so the sugarcane border did not check the white fly Dr Rahman also found 'jantar' (*Sesbania* spp.) useless in this respect, when grown as a windbreak around cotton.

It is stated that the borer pests (*Sesamia inferens*) and (*Chilo zonallus*) and *simplex*, are pests on both sugarcane and maize and *jowar* but it is major pest on the latter and a very minor one on the sugarcane. The growing of maize and *jowar* as short season crops in among or around sugarcane can attract only those borers

and not the *Diatroea* spp. which is the borer mainly responsible for the 'dead hearts' in sugarcane. (*Vide* Final Report by K. A. Rahman on *The Punjab Pink Spotted Bollworm Scheme and Annual Report for 1941*). In the case of the *jowar* earhead fly (*Calocoris angustatus* L.) a certain amount of reduction of the spread may be secured by the growing of redgram as a mixed crop (which is a common practice in case some two or three rows of this crop should alternate with the *jowar* in the manner of 'strip' cropping. In fact the author does not remember to have seen this fly pest to any great extent in *jowar* growing tracts where mixed cropping with redgram is largely practised. What other observers may have noticed it will be interesting to know. Two of the worst pests of dry land food crops in Mysore viz., the Deccan grasshopper and the hairy caterpillar (*Amsacta albistriga*) attack not only the *jowar* and *ragi* but also all the usual mixed crops, viz., young redgram young field beans, and other pulse crops and so on. Although the fact that both main crops and mixed crops form hosts to the pests and this may be tantamount to sowing a single crop as far as facility for spreading is concerned, it is also possible to regard it as a protection or atleast a factor tending to reduce the pest to that extent on the main crop. It is as a matter of fact so regarded by many cultivators.

Likewise the ' plume moth pod borer ' of field bean which is a bad pest on this crop equally attacks the red gram pods, and this circumstance may in the case of mixtures be looked upon as an ameliorating factor. The same remark applies to the stinking bug (*Coptosoma*) which is common to the above two crops.

In the case of the eel-worm, *Heterodera marioni*, an interesting instance of the use of the tomato crop as a 'trap crop ' is mentioned. On a small scale it was found that tomato plants withdrew 98 per cent of eel-worms in a single planting and that cowpeas withdrew up to 30 per cent. Total eradication of eel-worms was however not possible as even after 16 plantings the pest was not completely removed. It however forms a good example of a trap crop, (Phytopathology XXIV 6, 635—658, *Godfrey & Hoshino and Godfrey & Hagan*). Sometimes the date palms (*Dactylis sylvestris*) is considered as a trap crop for the cocoanut beetle (*Oryctus rhinoceros*) and is believed to attract the beetle away from the cocoanut trees to themselves and thus to protect the cocoanut trees. Likewise bushes of *Euphorbia tirucalli* and clumps of plantain trees are considered as repellents for this beetle and are for this reason often planted around cocoanut plants especially the young ones. Many of these beliefs have not been tested in a systematic manner to find out to what extent they are correct.

As a protection though not against insects but against the larger animals like stray cattle, jackals, wild pigs, etc., a certain amount of crop mixture is resorted to. The most familiar example is the growing of safflower as a border crop all round the main crops like Bengal gram, wheat, or *rabi jowar*. As the safflower is a spiny crop cattle do not touch it nor cross over to the main crop which they can eat. Some varieties of sugarcane which are soft rinded and are subject to a lot of damage by jackals and wild pigs are like the *pattapatti* (striped) cane of Mysore very superior in yield and quality. On account of this risk of damage by these animals, such canes cannot be grown at all in certain tracts. In order to get over this difficulty

the practice prevails in such tracts to plant a hard rinded cane like the *cheni* or the *marakabbu* all round the field and plant the *pattapatti* inside this protective belt. In addition sets may be planted here and there in the interior also along with the *pattapatti*, almost in the nature of a mixed crop.

It is also possible that in the case of insects attacking the roots of plants, such as the wire worms, and various cockchafer grubs and mealy bugs and so on, an immune crop interposed as a mixed crop may intercept the free movement of the pest from row to row of the susceptible crop and thereby afford protection to the main crop to a certain extent.

On the other hand far from acting as a beneficial agent a mixed crop may prove positively helpful to the spread of pests in certain cases. This is due to the fact that fields with mixed crops do not admit of the thorough interculture which may be necessary to stir up the soil in certain stages and destroy the pupae or expose their hiding ground. When crops are grown in rows far apart or chess board fashion, it is possible to harrow with bullock implements like the bladed harrows thoroughly between the rows and in the second case both along and across. A case in point relates to the castor semi-looper insect pest which is very destructive to the castor as it defoliates the crop seriously. Pupation takes place both on the dry leaves on the plant and also in the ground below, and if a good harrowing can be given, many pupae may be destroyed ; but the presence of an inter-crop like horsegram or ground nuts, which are both common makes this harrowing impossible, thereby helping the emergence of another brood in the crop season itself. The late Dr Kunhi Kannan, Entomologist in Mysore who studied the pest closely used to complain of this parctice as a serious hindrance in controlling this pest. It must however be mentioned that even in mixed cropping, where sowing is in rows, these are sufficiently wide apart for one or two hoeings with interculturing implements with hoepoints and with bladed harrows with blades about six or nine inches in length. The above instance must therefore be considered rather exceptional although from the point of view of plant sanitation through clean cultivation, this particular aspect of facility for interculture cannot be underestimated.

The shade provided by shade trees in coffee estates is inimical to the spread of the coffee stem borer beetle pest (*Xylotricus quadripis*, Ch.) or rather, the light let in when shade trees are removed or which is a feature of estates with insufficient shade, is very favourable to the spread of the pest. Whether the shade or the shutting in of light which results from the presence of mixed crops in between the rows of a main crop has a similar restraining effect on any pests of field crops and if so, what they may exactly be is a matter for special observation.

Some shade trees have the reverse effect in certain cases when they form alternate hosts to the pests of the cultivated crop and thereby perpetuate the pest and render control measure ineffectual. The 'shot hole borer' which attacks the branches of robusta coffee is also present on the *Erythrina* trees which form the temporary shade or nurse trees in such plantations. The troublesome leaf eating caterpillar (*Eupterote*

canaraica M.) on cardamoms takes shelter in the shade trees and makes control measures difficult.

The interaction of one crop with another as good or bad from this point of view of pest and disease control deserves greater study and in respect of at least the common mixed crops, or in the words of Dr K. A. Rahman 'in all cases of mixed cropping, the entomological aspect should receive adequate attention to avert both disappointment and disaster.'

Plant diseases

The above observations in regard to mixed cropping with reference to insect pests apply more or less to plant diseases also, *mutatis mutandis*. An immune crop or variety of the same crop interposed in rows or broadcast in among a susceptible crop or variety not only breaks or checks the progress of a disease but also reduces the loss from the cultivation to an extent proportional to the ratio of the immune mixture. This may be seen strikingly in the case of coffee (arabica) where in the midst of ordinary arabica badly attacked with red leaf disease and almost with bare branches may be seen many bushes said to be hybrid or other strains (like Kents for example) which stand out conspicuously with a good leaf cover, the contrast being very striking indeed. All resistant types of different crops afford a similar example. The immune crop or variety yields a crop and thus serves an insurance against total or very great loss which may otherwise result. Of course such varieties can be used in mixtures only if they are suitable in other respects also.

A mixed crop of low growing habit in between a crop with a taller habit has been found to exercise a palliative action against diseases to which the latter may be subject, from the fact that the intercrop reduces the soil temperature near the surface of the ground and thereby makes the soil less favourable to the development of certain fungi. Thus the growing of a mixed crop of *P. aconitifolius* with cotton resulted in a reduction in the mortality of the cotton plants due to root rot and had thus a protective effect. It was noteworthy that the disease became more evident when the ground was insufficiently covered by the mixed crop, as during the first fortnight of the growth or where the growth was patchy, thereby connecting the presence of the mixed crop and the checking of the disease as cause and effect. It is however stated that this beneficial action was seen to be greater in the case of American cotton than in *deshi* cotton so that the need is made out for a study of the mutual reactions of crops in this regard also. R. S. Vasudeva reports similar protective action exercised by a crop of *jowar* in between cotton, which shows that the shade is the principal factor whether provided by a low growing or tall growing crop. Experiments in Indore (reported by K. Ramiah) reveal some striking results in growing cotton of two distinct species like the *hirsutum* (American) and *deshi* (arboreum) in mixture. The practice is said to be general among cultivators and the results of experiments indicate among other important facts.

(1). The incidence of red leaf and leaf roll to which the American cotton is very much subject is distinctly less in the American cotton grown in association with

deshi than in the pure American cotton grown. (2). The *deshi*, component, which is susceptible to the fusarium wilt present in the soil, gets some protection from the disease, particularly in the early stages, when grown in association with the American which is immune to the disease. (3). The final yields of the mixture were either equal to or even greater than those of the pure types according to the season.

The mixture thus proves as far as disease is concerned, advantageous to both the components of the mixture, each protecting the other against the particular disease to which they are severally subject. It will be most interesting and useful to know whether in the many combinations described in this article there are any which may exert such a markedly beneficial action mutually upon each other in respect of disease control in the same manner as the above instance.

Whether the reduction of temperature and the increase in humidity near the surface of the soil brought about by a low growing mixed crop, can always be considered to be beneficial in this way may perhaps be doubted, as the same factors may exert a favourable effect on other fungi both above ground and below ground, such as the different mildews, damping off fungi and others which generally spread with greater ease in a moist atmosphere. That so much shade is very favourable to the spread of disease is instanced by the Pink disease (*Corticum salmonicolour*) of rubber, which is favoured by shade and which is checked when the shade is reduced. Other instances where the presence of a mixed crop is likely to prove favourable to the spread of disease may also be pointed out. Thus when there exist as mixtures either in the shape of deliberately mixed field crops or in the shape of natural mixed vegetation, plants which are hosts to any main or other crop, then this mixture proves a great hindrance in controlling the disease, and helps in both spreading and perpetuating it. The 'oideums' of several species which attack plants of the cruciferous order very largely find in a mixed crop of plants belonging to the order, such as turnips mustard, rape, or the vegetable crops radish, cabbage, etc., or the weeds of that order a favourable factor in spreading over the whole field. In the case of the 'Kole roga' of arecanuts (*Phytophthora areca*) it has been found that the presence of sandal trees in or about the garden or of plants *Coloccasia* spp. is helpful in perpetuating the disease as they help in the propagation of the disease, by furnishing one of the elements necessary in spore formation.

A similar mixture in which one crop acts as a favourable factor in spreading or perpetuating a disease to which another crop in mixture with it, is when solanaceous crops like potatoes, chillies, brinjals tomatoes, etc., are grown together or when weeds belonging to this order infest the field. The bacterial wilt disease (called 'ring disease' in the case of the potato) attacks all these crops and mixtures and even rotations of these have to be avoided.

As other examples may be mentioned, Hypochnus (*Corticium solani*) attacking plants of even different orders such as potato, tomato, cowpeas, groundnut, and Trichosanthes ; mildew (*Oidiopsis taurica*, Lev. *Erysiphe taurica*) attacking chillies, brinjals, *guar*, fenugreek, garlic, fennel ; white rust (*Cystopus candidus*) attacking a number of cruciferous crops, and weeds, the downy mildew (*Perenospora parasitaica*) the *Erysiphe cichoracearum* on *bhendi*, and on many cucurbitaceous plants.

In the case of certain root diseases of rubber caused by species of *Fomes* and *Poria hypobrunnea*, it has been found that some of the crops used as green manures viz., *Crotolaria anagyroides* and *Teprosia vogelli* are very susceptible to the same disease and under normal circumstances have to be avoided. Curiously enough this very property of these crops is taken advantage of for the purpose of locating the rubber trees the roots of which may have been attacked and which have to be removed and burnt, so as to protect the healthy trees from infection. If these crops are grown throughout the estate, then, wherever diseased rubber trees are present, these green manure crops become infected and diseased patches show up conspicuously and help to locate diseased rubber. They serve as 'indicators', so that the rubber trees around these centres of diseased green manure plants alone can be uprooted and destroyed, and the spreading of the infection of other rubber trees checked.

The clean tillage of the soil, and the removal and burning of weed and other unwanted vegetation which are important measures of disease control and plant sanitation considerably militate against the system of mixed crops or vegetation and only a close study of the interaction of crops on each other in this respect can reveal what the safe combinations may be or to what extent the advantages can be balanced against the harmful effects and the system can be profitably adopted. On the whole, it may be said that as long as mixtures of the kind referred to above are avoided, the system of mixed cropping may be considered more helpful rather than otherwise in respect of the prevention of the spread of disease.

Reference may be made to the theory of the exudation by the roots of certain plants of poisons, which prove harmful to plants grown in association or nearby. Grass growing in apple orchards has been found to exert such poisonous action on the apple trees. Many causes other than the exudation of poisons by the grass roots have been discussed and examined, and it seems to be established now that the injurious effect of the grass is really due to some poisonous exudation (*Soil Conditions* and *Plant Growth*, by Sir John Russell, page 502). Under certain conditions a similar injurious action is exerted by the grass Cynodon dactylon on cotton ; the effect of the grass is unmistakable and the spread of the grass directly leads to a reduction in the growth and yield of cotton. The removal of this grass, involving as it does great cost, is one of the established routine of operations in the black cotton soil fields and every care is taken to rid the field of the grass. Whether in this case also the cause may be a kind of poisonous exudation of the same kind cannot be stated, but appears probable. The matter requires investigation.

It is a common belief that the roots of certain plants repel those of others and that these two kinds of plants cannot therefore be grown together. Whether this is really so, if true, whether it is a case of poisonous root exudation are all matters for future investigation. The author remembers experiments in which a large variety of plants was examined by being grown in association with *sandal* to determine their nature as host plants to the *sandal*, which were conducted many years ago by the Mysore Department of Agriculture. This was of course in connection with the question of root parasitism. A similar experiment on a wider basis in the case of the ordinary field crops in this connection may lead to important results.

MIXED CROPPING AND LABOUR SAVING IMPLEMENTS

The introduction of better implements in Indian agriculture has long been one of the directions in which it has been sought to be improved. These implements comprise tillage implements such as ploughs, cultivators harrows and hoes. Sowing implements or seed-drills, harvesting tools, threshing appliances, sugarcane mills and jaggery boiling appliances, water-lifting appliances and some miscellaneous ones like chaff cutters, carts, bullock yokes, bullock shovels, wheel barrows and the like. They have all as their object a better type of work such as deeper tilth, soil inversion, uniform sowing, greater efficiency in reference to each type of work, speeding up of the work, economy in labour or the ability to turn out more work with fewer hands and lastly a certain amount of comfort or lessening of strain whether for men or bullocks, tending to increase their efficiency. There is perhaps general agreement as to the need for securing all the above mentioned objects, except in the case of labour economy. It is desirable that such implements and methods should be introduced as will dispense with the need for a large amount of human labour on the farms and enable the cultivator to farm a larger area with a smaller labour force. This is considered by some as one of the most important needs of Indian agriculture, if it should ever enable the farmer to rise to a higher standard of living than he enjoys at present. The opposite view is also largely held that more efficient agriculture is possible only with small scale farming and that ameliorative methods should be found in co-operation, better organisation of credit, marketing and so on, but keeping as many people as possible on the land and not squeezing them out on to industrial or other urban occupations. Though much can be said in support of either view it cannot be denied that there is scope for considerable improvement in this matter of agricultural implements without the bringing about of any large transformation in the shape of a reduction of the rural population or of a state of largely mechanised agriculture. Much depends upon what kind of labour saving appliances one is thinking of, whether they are, for instance, of the tractor cultivation order with multi-furrow ploughs and later with self binders and threshing machines or combines and so on, or of merely improved implements of a comparatively humbler type which can be adapted to the bullock draft now available with the farmer but which will still be a great improvement on the present methods. If thus the introduction of labour saving implements is called for, it is relevant to consider to what extent the system of mixed cropping will suit or hinder or interfere with such introduction.

Among the various agricultural operations referred to above, it is well known that the shortage of labour is felt most keenly during the harvest. Even where normally there is a sufficiency of labour for ordinary operations, during the harvest season there is always acute scarcity and competition among land holders is great to secure such labour as may be available. Wages are high and much casual labour flocks to the villages during the season to take advantage of the situation. In the tracts of insufficient labour even in ordinary times the difficulty becomes very great and timely harvest is almost impossible and much loss on that account is not uncommon. At present the sickle is the only and universal harvesting tool for all

cereals and other crops which have to be cut down. In some cases as in the harvesting of irrigated *ragi* and even jowar in some tracts, the field has to be gone over and plant by plant has to be handled, for cutting the earheads, except where the earheads are removed after the sheaves are brought to the threshing floor. This perhaps is the last word in slowness in the harvesting of the grain crops. The question is, whether it will not be possible to improve harvesting methods so as to get over this difficulty for labour and to speed up the operation. Indeed so primitive and ancient are the methods of harvesting and the operations on the threshing floor, that they arouse deep and reverent interest in the visitors from the U. S. A. (that land of mechanised agriculture *par excellence*) because they recall to their mind scores of biblical stories of the days of the Pharoahs, if not of Adam and Eve, which they could never have imagined were actually to be seen in these modern days anywhere in the world. It may be recalled that as a harvesting tool in Europe and America the sickle has long gone out of use, and has given place to successive improvements like the scythe, the scythe with the cradle attachment the mower, the mower or the reaper with the sweeprake attachment, the self binder the header and lastly the combined header and thresher. It is really an extraordinary circumstance that the sickle should persist in India so universally and that we have not advanced even to the scythe stage. Some 40 years ago the matter of improved harvesting tool was taken up by the Mysore Department of Agriculture and an implement fit for ordinary bullock draft, viz., a mower and then a reaper were imported and tried for the harvesting of dry land *ragi*, which is the chief grain crop of the country. The implement was found quite suitable for bullock draft and capable of harvesting ten acres a day. There was general appreciation by even conservative farmers of this striking result and this large output of work as indeed was only to be expected, because with the ordinary sickle it will require some 15 to 20 women coolies to harvest a single acre in a day. The *ragi* crop is however very largely grown with a mixed crop of field beans and other minor crops which are fit for harvest only long afterwards. and one row of which alternates with eleven rows of the *ragi*. so that the *ragi* has therefore to be harvested but the mixed crop has to be left standing. This kind of selective harvesting was of course impossible with the machine ; and as the abandoning of the mixed cropping was too radical a recommendation at that time the whole question had to be dropped, in spite of its importance and of its promising character. Where crops which will lend themselves to machine harvesting can be grown pure, the introduction of harvesting machines will be a very desirable improvement ; it is as a matter of fact reported that in some wheat growing districts of the Punjab, a reaper is being successfully used. If only mixed cropping can be given up without any serious disadvantage, the use of such machines can be made general, the machines being owned either by individuals or co-operatively. Mixed cropping will therefore be a hindrance to the introduction of this much needed improvement and agriculture will have to be of the slow manual labour kind, as long as it has to continue. We must not overlook the fact that some other changes will have to come about, especially the prevention of lodging by an earlier harvesting of the crop and the growing of stiff-stemmed and non-lodging varieties, and other consequential changes in

harvesting, field stacking and similar routine to permit of machine harvesting satisfactorily ; there may be a little stubble left on the ground and therefore a reduction in the quantity of straw obtained, there may be a little rough handling of the sheaves and some more shedding of the grain ; these will have to be put up with and set off against the labour saving advantages of the machine. As a hindrance to the use of machines the system of mixed cropping will remain the most serious compared with which these are very insignificant matters.

In the harvesting of the groundnut crop also improvements in harvesting methods are urgently called for, as the present methods of having to use digging tools and manual labour makes the work both hard and slow. If on account of the scarcity of harvesting labour the digging is delayed then the ground (the reference is to the red soils of Mysore and South India) often becomes so dry and hard as to make even digging out of the question, as the cost then becomes prohibitive. Some kind of bullock-drawn implement, is a great need for this purpose, and this is fully realised by the ryots themselves as is evident from the variety of methods employed as alternatives to digging by hand. Thus in the case of irrigated groundnuts the field is given a watering immediately prior to harvesting, and is then ploughed with an ordinary country plough which brings up the nuts, which are then gathered by coolies. In the dry cultivation, on the black cotton soils a special bladed harrow with the blade set at a steep angle is used, which answers the same purpose. In the red soils where the ground sets hard, either a plough is used if possible or the stone threshing roller is first drawn over the field face which loosens the surface and makes ploughing less difficult. Occasionally ploughs of the potato digger pattern are used. All these are only possible where the groundnut is grown pure or where the mixed crop is such that it matures and is harvested before the groundnut. If the mixed crop is different and has to be left standing then these methods are not possible. Cotton, castor, tuver are of the latter type and will preclude anything but selective harvesting with hand tools. *Jowar*, *bajra*, millets are of the former type and their being used for mixture will not be a disadvantage from this particular point of view. Attention may be drawn to another serious disadvantage of mixed cropping in the matter of harvesting. In many of the mixtures commonly adopted, components are such as mature and become ready for harvest at the same time ; examples are rice-cotton mixture, *ragi*, cotton mixture. Harvesting in such cases except when it is carried out with very great care cannot but result in the knocking about and shedding of grain, of damage to the cotton branches especially if it is the American variety with its horizontal branching habit, and in a shaking down of the easily detachable cotton from the bolls and so on. The great care required to avoid or minimise these losses will make the harvesting even slower and more costly than it is already with the selective harvesting which is necessary in mixed cropping.

Mixed cropping has been found to be a serious hindrance in another important aspect also. It has been found in Mysore (at the Hebbal Experimental Farm) that over a series of years the ploughing of the field immediately after the years

harvest of *ragi*, i.e., about the month of November is more favourable to the succeeding year's crop than if the soil is left untouched until the ploughing season of the following year (see under heading number 6). It cannot be definitely stated whether the beneficial effect, is due to any conservation of soil moisture, to the more thorough weathering, or because it enables the soil to absorb the first rains of the following year to a larger extent or other causes. As however the result has been favourable, the practice has been recommended for general adoption. The practice of growing a mixed crop of field beam or some times red gram in the *ragi* makes it necessary that the ploughing should be delayed until after this mixed crop too should be harvested, by which time (say about the end of January or the middle of February) the soil surface becomes very dry and hard, making ploughing impossible. So to get over this difficulty, a six shovel cultivator, a disc harrow and such implements have been recommended and introduced, although these can stir the soil and can in no way be a substitute for ploughing. Were it not for the mixed crop a good ploughing can be given and the full advantage secured without having to be satisfied merely with this shallow discing or harrowing. It is interesting to add that the importance of this ploughing is well recognised in some parts of the state and ryots invariably plough the field between the rows of the mixed crops immediately after the harvest of the grain crop and for this purpose go to great pains in moving the vines of the field bean crop this way and that, so as to save it from damage during the ploughing. As a dry farming practice this ploughing has been found very beneficial, but mixed cropping renders it difficult to carry out or to be carried out in such a manner that the full benefit can be secured.

Mixed cropping as related to a balanced nutrition

It is a common observation that the diet of the people of India is insufficient and ill-balanced. While the total nutrition requirement in terms of calories falls short of what may be considered an adequate quantity per individual, the lack of the much needed variety in the shape of a proper protein supplement, and of even a carbohydrate supplement in the shape of oils and fats, together with a sufficient addition of the accessory or protective foods in the shape of milk or animal protein and vitamins is a matter which has been emphasised by nutrition experts. Leaving aside the question of a general insufficiency of food, which can be remedied only by a large increase in the production of food, it may with much reason be held that the system of mixed cropping makes a very material contribution towards remedying the other defects viz., the lack of balance. In all the tracts where mixed cropping is generally practised, a veriety of crops is grown both different kinds of food grains and pulses (including the groundnuts which is both a pulse and an oil seed) and largely included in the dietary of the local population. The diet of all farming communities in such tracts is composed of a mixture of the staple of the tract, as the main cereal, the chief pulse as the main protein supplement, with other grain and pulse crops which are grown to a smaller extent affording an appropriate variety. Groundnut, gingelli and safflower to the extent that they may be consumed as such supply considerable portion of the fats in the food. In

mixed cropping this is easily possible, as this variety of crops is grown unfailingly year after year. In the system of growing pure crops, on the other hand, such a variety can be secured only by the laying down of many fields or plots each devoted to a particular single crop and by the adoption of a suitable rotation which can include all these crops. In practice such a course will be found almost impossible and especially so for the small farmer. As a matter of fact there is a great deal more of the pulse crops consumed in households in the dryland tracts than in the delta and other tracts where rice is the single crop grown. 'In rice eating areas where pulses are most needed their intake tends to be smallest'. Moreover there is also considerably more variety in the kinds of pulses consumed in these tracts. In the pure rice tracts the *dal* of *Cajanus indicus* is the chief and about the only pulse consumed, and blackgram and greengram are consumed to a smaller extent, and some of the other pulses figure to an insignificant extent. All these moreover are purchased products and the consumption is therefore generally small. On the other hand among the farming classes in the dryland tracts where the system of mixed cropping prevails most, other pusles like field beans, horsegram, kasari lentils (*Lens esculentis*), Bengal gram all figure to a larger extent, in addition to the redgram, blackgram and greengram consumed in the rice tracts. Presumably then the diet of the mixed crop farmer is better both on account of the larger proportion of the proteids consumed in the shape of the pulses and by reason of the variety among them.

This matter requires however to be gone into a little more deeply, in order to appreciate its full implication and its practical bearing on mixed cropping. It can be elucidated only from the chemical point of view, on the basis of investigation into the composition and nutrition value of the different grains and pulses, and particularly the contents of proteids, their nature and characteristics from the nutritional point of view. What are their comparative values as suppliers of proteids in animal nutrition? At present the composition of the different pulses is largely given only in terms of the proximate constituents, such as proteids, starches or carbohydrates, fats and so on, and very little information is available as to the quality of these particular constituents, although it is known that their value as human food is very materially influenced by this factor and does not altogether depend upon the total percentage of such constituents. The different kinds of proteids (such as lysine, histidine, argenine, crystintyrosine and tryptophane) of which the total proteids are made up and their relative proportions have not been determined for all the different pulse crops of India nor have other important peculiarities like their biological values, digestibility etc., been determined both chemically and through nutrition experiments. Such data are lacking even in the case of individual pulses and much less are they available in the case of mixtures of the pulses with various cereal foods like rice, wheat, *jowar* or *bajri*. The same remark applies to the composition and character as human foods of these staple food grains themselves. In the absence of scientific data of this kind it will be impossible to assess the value of the different foods whether cereals, pulses or oil-seeds, either by themselves or in various combinations. That differences do exist other than or even contrary to what one may infer from the proximate composition

in terms of the total percentage of each food element, is a belief almost universally held in the country, both as the result of actual experience and according to the teachings of indigenous medical systems. Such differerces are a matter of every day experience in Indian households and there is altogether an astonishing amount of what may be called ' kitchen lore ' in the possession of our womenfolk regarding the differences in quality, behaviour and suitability or healthfulness, of these various food materials, both in themselves and in mixture with one another. Thus green-gram is supposed to be the most easily digestible among the pulses, cowpeas, field beans, and Bengal gram *dal* are hard to digest, and have a tendency to produce flatulence, red gram *dal* as tending to promote growth, black gram as about equal to animal food, ard so on. That blackgram is quite different from others is easiest to notice ; the dough is mucilageous and plastic and indeed is used as a plastic adhesive like casein in closing leaks in sugarcane juice boiling pans. It is also sometimes stated that its use was popularised by Budhist monks as a substitute for meat. To what extent these beliefs have a scientific basis and can be taken as correct cannot be stated as matters stand at present with the very meagre almost negligible scientific data available.

The practical value of such definite knowledge in this respect may be said to be two fold, viz., in determining what will be the best mixtures of grain and pulse and whether and to what extent one or the other of the pulses may be used as substitute for proteids of animal origin. Taking the question of correct mixtures attention may be drawn to the fact that in the daily dietary of the people it may be noticed that it is red gram *dhal* that largely goes in mixture with rice field bean *dhal* with *ragi*, Bengal gram with wheat or barley, and many kinds of pulses with the dry grain *jowar*, *bajri*, and the millets. This preference to one or the other of the pulses may be merely due to the fact that such pulses happen to be cultivated in the tract and are therefore locally available and are therefore dictated only by convenience and that no special significance can be attached to them.. It must be said on the other hand that apart from this circumstance, the pulse crops red gram, field beans Bengal gram and perhaps lentils enjoy special popularity and are to be regarded as major pulses and are always secured either from local grown produce or if necessary from outside, so much so that the preference has something more behind it than mere convenience. Just as in the case of the cultivation of the mixed crops some may be regarded as compatible mixtures and others cannot be so regarded, similarly in their use as mixtures in food with particular cereals and pulses some combinations may be advantageous and others not. Perhaps compatibility on the field as disclosed by present practices may be parallel with compatibility on the table as food. In any case it is obvious that those pulses which should prove the best mixture with any particular cereal grain as a food should be the most desirable for mixture on the field also, provided other agronomic considerations are not against such mixture. The suggestion made ' it will be appropriate to divide the country into different regions irrespective of provincial and State boundaries such as a rice region, a wheat region and a mixed region and to work out the requirements and availability of foods in respect of those ' deserves to be taken up, for more

reasons than those contemplated by the authors (*I. C. A. R. Memorandum on the Development of Agriculture and Animal Husbandry*, p. 17).

Reference may now be made to some interesting results of an investigation into the comparative merits in regard to their biological values of certain pulses when used as mixture with rice. The pulses taken up for this investigation are red gram, black gram, green gram, Bengal gram and soya bean, and the grain taken up was milled rice (not par-boiled). Comparison was also made of the pulses in the same mixture with the addition of skimmed milk. The results as far as they relate to the first series alone are given in the Table VI.

TABLE VI

Biological values of certain pulses when used as a mixture with rice

Sources of proteins	Biological value	Digestibility coefficient	Average increase in body weight
Raw milled rice plus red gram	70	81	7·4
Raw milled rice plus soya bean	68	84	6·5
Raw milled rice plus Bengal gram (*Cicer arietinum*)	66	85	6·8
Raw milled rice plus black gram	61	82	5·9
Raw milled rice plus green gram	59	90	7·5

It is seen that when pulses are eaten with rice, green gram (*Phaseolus radiatus*) and red gram (*Cajanus-indicus*) appear to act better than Bengal gram or any other variety (Swaminathan, M. 1937, *Ind. Jour. Med. Res.* Vols. 1 and 2, pp. 24 and 25).

Investigation of this kind carried out with the other important grains like wheat, *jowar*, etc. is likely to lead to interesting and important conclusions on this matter and is therefore to be very strongly recommended. It has to be remembered that in respect of the portein content and its character the grains differ considerably from one another. Moreover the proteins of the grains appear to be sharply distinguished from those of the pulses and also of other kinds of produce. Thus the biological value of the protein in those of the grains were found to be as follows :

Ragi, 89·9 ; rice (polished), 80 ; *jowar*, 83 ; maize, 60 (B. N. Acharya, S. P. Neogi, and V. N. Patwardhan, in *Ind. Jour. Med. Res.* 1942, p. 79).

Ragi, 89 ; rice, 80, *jowar*, 83 ; *bajri*, 83 ; Italian Millet, 77 ; wheat : 66 (Swaminathan, M., 1938 *ibid*).

In regard to the distinct nature of the proteins in the cereals as against those in pulses, attention may be drawn to the conclusions by Staker and Gortner, viz., ' the peptonisation behaviour of the various groups of related seeds (such as grains,

pulses, oilseeds) appear to be rather distinct and characteristic of each group' (Physico-Chemical Studies on Proteins, E. V. Staker and R. A. Gorter, *Jl. of Phy-Chemists*, 1931, pp. 1565-1605). These authors further remark that the whole question of protein individuality, protein classification and protein isolation needs to be critically studied.

We now come to the second point, viz., if the proteins of any of the pulses are allied in composition to proteins of animal origin closely enough to admit of their use as a substitute for the latter partially or fully, and again if a mixture of the pulses will make it a more efficient substitute for animal proteins than single ones. These questions are of particular importance in a country which is so largely vegetarian in its food as India, where on this account the supplementing of the usual food with animal proteins in the form of milk and milk products is very much stressed as that is about the only form of animal proteins which may be acceptable to the stictly vegetorian classes. If one or more of the indigenous pulses can to any extent be used as a subtitute for auimal protein then the problem of nutrition becomes somewhat less difficult. As everybody knows, the same extent of land can feed a larger number of people if it grows food for direct human consumption instead of as feed for livestock which may in turn furnish human food either as milk or as meat, or in other words, that a vegetarian population can subsist on a smaller area of land than a meat eating population. A positive finding with regard to the value of the pulse proteins as substitutes for animal proteins will therefore lead to very important results. Unfortunately (as far as we are aware) little or no research has been carried out in elucidation of this aspect of the question.

R. K. Pal in his review of the literature on this subject has attempted to assess the comparative values of the pulses in this respect by combining together all the data regarding biological value, digestibility, total protein content, net protein value, and percentage of cystine, tyrosine, tryptophane and histidine. Arranged on this basis Bengal gram and black gram both stand first in the order of merit, and green gram, lentils, cowpeas, soya beans come next in order ; red gram, horse gram follow next, and field pea, field beans, and *khesari* come last (R. K. Pal, *Ind. Jour. agric. Res.* Vol. IX, Part I, 143).

The different aspects of this complex problem require to be studied, both chemically and biologically and the importance of such studies cannot be over emphasised. Conclusions of the greatest value are likely to be reached which can be made use of in the recommendations for suitable mixed crops of pulses to different cereal regions in the country.

MIXED CROPPING AND UTILISATION OF SPACE

One of the chief motives in resorting to mixed cropping is certainly the object of utilising all the space possible for the raising of crops, rather than leave any portion of the field bare of crop. The whole of the area has to be ploughed or dug, cleaned of weeds and brought into a good state of tilth and manured, and later irrigation, weeding, watching and general attention has to be paid in any case ; why should not all these facilities created at great cost and labour, be utilised to the fullest extent

possible ? Failure to do so only means woeful neglect and waste which no cultivator can afford. If suitable mixtures of crops can be arranged, so that this object may be attained without serious interference of one with the other such mixed cultivation should be considered the best in the interests of the farmer and one calculated to make the best use of manure, labour and land. It is largely some idea of this kind that underlies the system. The idea is very clearly seen in many vegetable gardens ; around Bangalore for instance a favourite mixture is knolkohl, and sabsige (*Peucedanum graveolens*) and *chakotra* (*Atriplex hortensis*) which are sown together. The *chakotra* is pulled out first, then comes the sabsige and lastly the knolkohl. Another mixture is *chakotra* and amaranthus sown together and a month later celery transplanted in among them. The first two are removed one after another and the celery covers the ground completely and is harvested after three months. Likewise amaranthus, carrots, English radishes, knolkohl are all sown together and are removed one after the other, the carrots being the last to be pulled out. Cauliflowers or cabbage are planted in mixture with chakotra, sabsige and amaranthus, these last are removed first, and then the cabbage and cauliflower cover the ground completely and are removed in from three to four months. Along the margins onions are sown and these are removed in six to eight weeks. In all these cases the quick growing crops are sown in among the more leafy and long duration crops like cabbages, cauliflower plants, so that the former can be gathered and removed by the time the latter grow sufficiently large to need and occupy the full ground ; to leave the ground bare until this time is considered wasteful, and hence these catch crops are sown ; a succession of crops is the result giving some money income every time ; the quick growing crops shade the slow growing seedlings and give protection and the gradual removal of the catch crops result in a certain amount of forking but the money income for the full utilisation of the space is certainly the main consideration. Some crops can be so grown that they do not take any ground space worth mentioning and therefore without competing in this respect with a long duration crop, because they can be trained on poles and vegetative growths carried up clear of the ground. A most curious instance of this kind was the training of the creepers of vegetable crop (bitter gourd) over strings reaching from the ground to the eaves under the roof, leaving the ground free for other crops ; another familiar example is the training of creepers of some kinds of beans over upright trellises rather than over overhead frames *pandals*, so as to economise space. This has its counterpart in field husbandry in the growing of maize or fodder *jowar* with climbing vines like cowpeas or horse gram.

In the case of catch crops in among sugarcane, in the early stages when the sugarcane is very young and has not tillered and grown leafy enough to preclude catch crops, it is a natural desire to utilise the space between the rows for some mixed crop. So in the case of cotton and castor, the desire to grow an inter crop during the time that they take to grow large and bushy enough to preclude it, is natural. If there should be no mixed crop of this kind, weeds will in any case come up and occupy the ground and will necessitate frequent hoeing with bullock or hand tool ; the growing of the inter crop prevents such usurpation and substitutes a profitable crop for a pest which has to be removed at considerable cost.

the best results were obtained from growing groundnuts in association with *jowar* castor, red gram or cotton (although in all cases the yield of groundnut in mixed cropping was depressed).

In the United Provinces it has been reported that growing groundnuts between rows of red gram has been profitable.

(*b*) *Mixed cropping is not profitable.* Experiments in some stations in the United Provinces have shown that the local practice of growing mixed wheat and gram on irrigable black soils is less profitable than sowing wheat and gram in rotation.

At the Cotton Breeding Station in Coimbatore the mixing of pulse with *jowar* did not benefit either the *jowar* or the succeeding crop of cotton. The pulse reduced the straw yield of *jowar*.

At Nandyal, Pillipesara (*Phaseolus trilobus*) in mixture with *jowar* had a depressing effect on the yield of *jowar*. At Guntur there was no increase in yield in growing this mixture.

At Hagari, in the Cotton-*Setaria italica* mixture the yield of cotton was lower than in the pure cotton crop.

At Koilpatti, Bengal gram, horse gram and coriander were grown mixed with cotton and compared with cotton grown alone. The monetary return of the mixture was less than that of cotton alone. At the Central Farm at Coimbatore, mixed crops of cotton were not found profitable financially, as the price of cotton at that time was very high.

The depression in the yield of groundnuts in mixed cropping observed in the Thindivanam Station has already been referred to.

(*c*) *Results inconclusive.* At Koilpatti various other pulses (than red gram and horse gram, already mentioned) tried along with cotton led to no definite conclusions.

Mr. Rangaswami Ayyangar concludes, by saying that experiments conducted at various Agricultural Stations have not led to any definite results with regard to the suitability of any particular subsidiary crop or the benefit derived by growing such mixtures.

The experiments conducted in the Madras Presidency nearly all of which have been referred to above are summarised in greater detail in a note by the Director of Agriculture, Madras (vide. Appendix II). The Director observes 'with the exception of a few Stations, viz., Guntur, Palur and Thindivanam, the pure crops gave the highest money return. At the three stations mentioned above the rainfall and soil conditions were obviously favourable for crop mixtures'.

In experiments comparing the yields from wheat-gram mixture with those from wheat and gram grown pure conducted in the Nagpur Farm, Central Provinces, the financial advantage was in favour of the rotation of wheat with gram both being grown pure as compared with a wheat-gram mixture every year, although the difference was not very striking. The wheat yielded at the rate of 895 lb., per acre in the pure crop and the gram yielded 453 lb., as against 553 lb., of wheat and 145 lb., of gram (all averages over a period of 16 years) so that taking a two year crop, the mixed crop gave on an acre 1,106 lb., of wheat and 290 lb., of gram while the pure crop gave only 895 lb., of wheat and 453 lb., of gram. The total

grain during the two years period was more in mixed cropping but the gram was less. Financially the pure crop is reckoned as having scored. In another experiment designed directly to compare the two systems with wheat and gram carried out over a period of ten years, the average yield of the pure crop of wheat was 348 lb., per acre while that from the mixture (two thirds wheat and one third gram) was 244 lb., of wheat and 119 lb., of gram. Calculated proportionately the wheat yield from the mixture will work out somewhat (but very little) higher than in the pure crop, being 244 plus 128 or 366 lb., per acre as against 348 lb., in the pure crop. Taking only the crops actually harvested the financial result here also is stated to be in favour of the pure grown wheat crop, (vide pages 348-351 a consolidated recotd of the Fievd experimental works carried out by the Department of Agriculture in the C. P. between 1900-1930, by R. G. Allen). These experiments are very noteworthy because they have been carried out over a fairly long period, viz., 16 years and 10 years respectively.

It is reported by the Director of Agriculture, Bhopal, that 'economic results of mixtures are better than sown pure.' The report gives the yields of individual components of mixtures of different crops with wheat, but does not give comparative figures for pure crops. It is also stated that the following proportions have been found the most profitable, viz., wheat and linseed 50-50; wheat and gram 75-25; and gram and linseed 50-50.

In Mysore the question has been studied in considerable detail, and from more than one angle, viz., in relation to the use of a better harvesting implement, in relation to the ploughing of the fields in the autumn, in relation to the conservation of soil moisture and lastly in relation to the sowing of pure selections in preference to the sowing of mixtures. The work as it relates to each of these aspects has already been noticed in the respective headings.

Comparative experiments to find out the yields and financial returns from pure and mixed cropping were laid down in 1915 and were continued for four years until 1918. The comparison was between *ragi* (*Eleusine coracana*) grown pure and *ragi* grown in mixture with field beans (*Dolichos lab-lab*) which is the customary method prevalent in the state. The experiments were quadruplicate plots and the results were as in Table VII.

TABLE VII

Grain in lb., per acre

——	1915	1916	1917	1918	Average for 4 years
Ragi pure	440	675	850	314	570
Ragi mixed with field bean and *jowar*	325	807	780	120	508
	142	152	52	88	109
	77	121	40	..	60

'The results indicate pretty clearly that the growing of a mixed crop is more profitable than the growing of a pure crop. If we exclude straw the average value per acre of the pure crop was roughly Rs. 18 and that of the mixed crop roughly Rs. 25 per acre.' Comparisons have been made in subsequent years also with the same result, viz., the mixed cropping was found more profitable financially. Dr Coleman however observes 'notwithstanding this considerable difference it is still quite possible that the advantages which accrue from early ploughing which can be done only when a pure crop of *ragi* is grown would outweigh the undoubted increase due to the mixture with a pulse crop. This must however remain a subject for future investigation'. (The Cultivation of *ragi* in Mysore by *Leslie C. Coleman*, *Bulletin No.* 11, *general series* ; *Mys. Dept. of Agric.* 1920, pp. 11 and 12).

An interesting instance of a profitable form of mixed cropping is reported from the Indian Sugarcane Station, Coimbatore, although the crops concerned in this mixture are only green manure crops. In this Station the practice of growing mixture of two green manure crops together in preference to pure single crops was commenced in 1936-37. The mixtures were (1) field beans (*Dolichos lab-lab* and *pillepesara* (*Phaseolous acontifolious*), (2) field beans and sannhemp and (3) sannhemp and *pillepesara*. It was found that (*a*) the mixture was a better cover on the soil and that it suppressed weeds more completely and (*b*) that the yield of green material from the mixed crop was 30 to 40 per cent higher than from the pure crops. (Letter to the author from Mr. Nanda Lal Dutt, Government Sugarcane Expert, Coimbatore).

PART II

Mixed cropping with reference to some of the principal crops

Rice

It may be thought that the peculiar conditions under which rice is almost universally grown, viz., under irrigation which is so copious and continuous that water has to stand in the field several inches deep, and is often grown under absolutely flooded conditions where water stands several feet in depth, no mixed cropping will be possible as few or no crops of agricultural importance can grow under such conditions. Nevertheless the advantages such as they may be of mixed cropping are so highly recognised that strange as it may seem, mixed cropping is practised even with this crop. The mixed cropping under these conditions takes the form of growing two varieties of rice itself, and not a crop different from rice. The varieties grown are either rices with different periods of maturity, such as one maturing in four months with another maturing in seven or eight months; or rices which differ in their hardiness, such as one which requires steady and ample irrigation with one which is not so exacting in its requirements for irrigation and will stand a certain

amount of insufficiency of water ; the varieties also differ in their quality, one being fine and the other less so if not definitely coarse. These two different kinds of mixtures illustrate very clearly the two main considerations underlying the practice of mixed cropping in general, viz., 1. a more economic utilisation of time or the length of the crop season, of the area available for cultivation and of the labour involved in cultivation and 2. a kind of partial insurance against a total failure od crops.

The following are the mixtures which come under the above two classes :

1. *Mixture of two varieties of rice*—In the Cauvery Delta in the Tanjore District of Madras, the system prevails of growing the Kuruvai variety of rice as a mixed crop with the Ottadam variety. The former is a four months variety and the latter takes eight months. The practice is to mix the seeds in the rates of one of Ottadam to four of Kuruvai and sow the mixture in a nursery and later on transplant the mixture of seedlings ; both grow together and the Kuruvai matures in 3 to 3½ months. The whole field is now harvested, the grain being only the Kuruvai and the straw a mixture of the two varieties. Incidentally it will be seen that the Ottadam straw is not straw in the strict sense but is really a kind of hay, that is grass cut green and before the grains formed and drained it of its nutrients. The Ottadam now grows from its stubble and matures a crop in another three to four months and is harvested in its turn. This is a truly remarkable practice and it may be doubted if it has its parallel anywhere. The Kuruvai matures in its own peculiar season and the Ottadam in its own season. The alternative if two pure crops have to be grown will be to grow the Kuruvai in the early season and another short duration crop in the following half of the crop growing season (which in the mixed crop system is occupied by the Ottadam crop) ; this part of the season may or may not be suitable for this purpose and an assured or successful crop may be doubtful, in any case. If the Ottadam has to be grown pure, it will take eight months to mature and at the end, the crop may be full or only partial depending upon the seasonal conditions, while the long interval of eight months may be really too trying for many ryots and for their cattle, as few among these have a sufficient reserve of grain and fodder to enable them to carry on for such a long time.

It is not known whether there are any economic advantages in growing these pure in the above manner, sufficiently great to weigh against the mixed cropping to what extent, that is to say, the yields from pure grown Kuruvai and pure grown Ottadam are higher than from mixed crop growing and if so whether such yields can be counted upon over a long series of years under conditions prevailing in the tract.

Experiments have been conducted with another alternative to this method viz., growing a mixture of short and long duration varieties in comparison with a pure crop long duration variety. It was found that with a particular short duration variety (viz., Adt. 3), the combination gave a larger yield than the pure long duration crops (Maratur Station, Madras Province). Similar experiments on the Samalkot Farm (Madras Province) showed that the yield was the same both with the single cropping as well as in the mixed cropping, and that the latter was in addition found

to involve more expenditure. It is stated that in Tanjore the practice is now on the wane, and that in the Godavari Delta ' the system is definitely unremunerative for lands of average fertility or where the planting has to be done late ' (*K. Ramiah* in ' Rice in Madras ', pages 64 & 65).

We may point to one advantage of a pure Kuruvai crop, viz., the possibility of growing a leguminous fodder crop after the harvest of the Kuruvai. As the cultivation of rice will not permit of a rotation with other crops (except in special cases and in any case to a very small extent, such as where sugarcane, plantains, betel vines, turmeric, tobacco, etc., are grown) and as the need for some nutritious fodder is always great in these tracts where the condition of the cattle is deplorably low, such fodder crop growing may be a desirable practice, if the soil and other conditions will permit.

In the Cochin State a very similar or almost identical practice prevails, in which two varieties of rice called Veruppu and Mundakam are grown mixed. The following is a description of the method :

' The Virippu seed is a short duration seed, four to four and a half months in duration and the Mundakan seed is long duration seed standing in the field for eight months. Both the seeds are sown mixed together in the month of May. The Virippu (short duration) seed grows tall quickly, flowers earlier and it is harvested in September. At the time of the harvest of the Virippu crop the plants of the Mundakan crop remain stunted in the field, almost completely enveloped underneath the Virippu paddy. The plants of the Mundakan crop are not cut at all along with the Virippu harvest. After the Virippu harvest is over in September, the Medom crop which remained smothered under the Virippu crop till then, grows quickly in height and thickness and completely covers the field (Director of Agriculture, Cochin State).

It may be observed that many rices yield a small crop of grain from the stubble, if the latter is allowed to grow. It is not known whether the early variety in the above cases gives any such crop at all ; if it does then the later harvested rice will contain grains of the early variety also mixed with it, which will be a feature much to be deprecated in this practice of mixed cropping.

A very similar system of mixing together of two varieties of rice and growing them together prevails in Bengal and is described by Mukerji (*Text Book of Indian Agriculture*, by N. G. Mukerji). This is his description.

' A peculiar kind of boro rice is known as rayada or *bhasa-naranga.* This is sown along with ordinary boro-rice in December. The young stems are shorn when the young crop is removed, but this does not seem to do the rayada any harm. It continues to grow in water attaining to a height of 10 or even 20 feet and is not harvested till September or October, thus remaining on the land for ten months. Only the ears with a foot and a half of straw are harvested, the rest of the straw or *nara* being left to rot on the land or gathered and set fire to.'

Similar mixtures of rice plus rice are reported as prevalent in many parts of Bengal, where the combination is of *aus* and *aman* rices.

2. *Mixtures of rice with other crops.* A crop other than rice which is sometimes grown in mixture with it under these heavily irrigated or flood conditions is Jute. The *aman* variety of rice is thus grown in mixture with jute (Capsularis) in the Districts of Dacca, Faridpur, Comilla and Rajshahi.

3. *Mixtures of rice with other (dry) crops.* While the above exhaust mixed cropping under the special conditions of rice growing, rice is grown as a mixed crop with a large variety of other crops under the ordinary rainfed conditions of dryland crops. In these situations rice is mostly a subordinate crop. The mixtures consist of one, two or more crops, and comprise cereals, pulses and other crops. The following is a list of such crops which number 16 in all.

Cereals

- *Jowar*
- Italian millet
- Maize
- Kodo millet (*Paspalum scrobiculatum*)
- *Panicum miliare*

Pulses

- Red gram
- Sann hemp
- *Kesari*
- Black gram
- Green gram
- Cluster beans
- Cowpeas

Other crops

- Cotton (*Tellapathi, G. herbaceum*)
- Gingelli
- Deccan hemp
- Jute

The total rainfall however sets a limit to the tracts where it can be grown, the heavy rainfall tracts of the ghat sections of the peninsular India, on both sides of the Western Ghats, of Eastern Bengal and Assam being unsuitable for the crop, nor the heavy North East monsoon season in the coastal districts of the east coast. In the main or *kharif* season the rainfall of the South West monsoon is too heavy for the crop in districts of the west coast and on the plateaus adjoining the Western Ghats on its eastern side.

Crops mixed with jowar. As in the case of other crops, so in the case of *jowar* also, it is not possible to say to what extent it is grown pure and to what extent it is grown mixed. Though there are many conditions and tracts where it is grown without any mixture at all, still the bulk of the crop throughout the country appears to be grown only along with a mixture of one or more of other crops.

As in the case of rice, *jowar* itself of two varieties constitutes a mixture. Thus varieties of fodder *jowar* are sown as mixtures with the food grain *jowar*, either in lines within the field alternating with a much larger number of lines of grain *jowar* or all round as a border crop. These fodder *jowar* varieties afford considerable green fodder in the season, for which purpose indeed they are thus grown. The following crops numbering some 34 in all are grown in mixture with *jowar*.

Cereals

Rice
Bajri
Italian millet
Maize
Varagu (*Panicum miliare*)
Kuduravali (*Panicum crusgalli*)
Wheat

Pulses

Red gram
Black gram
Cluster beans
Methi (*Trigonella foenum graescum*)
Gram
Matki
Horse gram
Sann hemp
Cowpeas
Green gram
Field beans

Other crops

Castor
Linseed
Safflower
Gingelli
Groundnut
Cotton
Mustard
Pundi (*Hibiscus cannabinus*)
Coriander
Indigo
Cucumber
Water melon
Vegetables like brinjals, *bhendi*, etc.

The mixtures sown comprise two crops or three crops or more than three. In Table IX all the different mixtures reported as prevalent in the country are given in a classified form under the above divisions.

TABLE IX

Mixtures of jowar

—	Cereals	Legumes	Others
With one crop	Rice *Bajri* Maize Italian millet *Panicum miliacsum*	Red gram Field bean Green gram Black gram *Matki* Horse gram Bengal gram Cluster bean *Methi* Sannhemp Groundnut	Castor Linseed Safflower Deccan hemp Mustard. Cotton Coriander Indigo Cucumber Gingelli
With two crops		Cluster beans	Italian millet
		Cluster beans	Castor
		Bajri	
	Bajri	Maize	
	Wheat	Red gram	Mustard
	Bajri	Groundnuts	
		Groundnuts	Gingelli
		Horse gram	Cotton
		Red gram	Jute

TABLE XI—*contd.*

Mixture of Jowar—contd.

——	Cereals	Legumes	Others
		Green gram and *matki* Red gram and green gram Cluster beans and *matki* Groundnuts and field beans Bengal gram Red gram Black gram and cowpeas Red gram and field beans Field beans and cowpeas Field beans and black gram	Safflower Gingelli
With more than two crops	Italian millet *Bajri* *Bajri* Wheat	Cluster beans and cowpeas Cluster beans and black gram Cowpeas and groundnuts	Safflower, linseed vegetables
	Jowar *Bajri* *Bajri*	Red gram and *matki*	Cotton and gingeli
		Red gram and black gram Sannhemp and cowpeas	
	Sanwa millet, *kudo* millet and red gram		
		Cluster beans, black gram and Green gram Red gram, black gram Redgram, *matki* Black gram and cowpeas Cowpeas, black gram Cowpeas, field beans and *matki* Cowpeas, black gram	Deccan hemp Deccan hemp Gingelli

It will be seen that the different mixtures listed number as many as 60 altogether, out of these the largest number, viz., 41 contain one or more pulse crops, 19 contain one or more cereals and 22 contain one or more of the many other crops mentioned. The mixtures are thus largely food crop elements comprising *jowar* as the main grain crop and a few subordinate food grain crops and a large number of pulse crops, not to mention the vegetable crops in addition. The crops other than food crops comprise those which supply the domestic needs of the farmer such as Deccan hemp, the fibre crop, the oil seeds, gingelli and castor, while the others like linseed, coriander, groundnut and others may be regarded as both money crops and as being grown for domestic needs. The *jowar* field especially in the black cotton soil tracts and during the *kharif* season may indeed be regarded almost as self-contained store houses furnishing the farmer with nearly all his main requirements.

Proportions of the components—In common with the other crops, both major and minor, *jowar* enters into mixture with other crops, whether it be two crop mixtures

or mixtures with more than two crops, in a number of different proportions. This indeed is a remarkable feature of mixed cropping. It is not as if any one particular proportion has been found to be the most advantageous either from the economic or the scientific point of view, in which case this particular proportion will be adopted solely or in a very prominent degree. The very large and striking variations in the proportions would appear to indicate that the individual needs or convenience of the farmer or other varying causes decide the proportion rather than any definite economic or other factor. In cases where certain proportions predominate, the habit of growth of the mixed crop such as that of red gram or field bean or cotton as distinguished from that of the grain crops like *ragi*, *jowar*, *bajri* or Italian millet, and the extent to which such habit would permit of the mixture without unduly suppressing the growth of either kind has apparently been the deciding factor. Ratios decided by this factor form the basic ratios, so to speak, and have become the customary ratios in the tracts concerned, and the numerous variations from these ratios have been due to the convenience or temporary needs of the farmer.

It would appear that in certain provinces (the C. P. and Berars, for example), certain definite proportions have been 'fixed' — (it is not known if this has been done by Government or only the custom of the villages) and that a similar state of affairs prevails in many other parts of the country as well. Alterations have been introduced as the result of the war and the prevailing scarcity of food grains, which increase the proportion of the grain crop in the mixture. Thus if three rows of *jowar* are usually mixed with one row of red gram, this is altered into six rows of *jowar* and one of red gram ; likewise if five rows of Italian millet are usually grown with one row of cotton, the former is increased to ten or more rows to one of cotton, thereby increasing the area twice or more. As a matter of fact this is what the cultivator himself has been generally doing in order to adapt the proportion to changing needs.

In this summary, it is not possible to give the proportions in the case of all the three different classes of mixtures. We confine the propotions therefore only to those mixtures in which one other crop is grown in mixture with *jowar*. The proportions in which *jowar* and one other crop are grown together are as below :

Cereals

Jowar to Italian millet, 3 : 1, 1 : 40, 1 : 12
,, *bajri*, 1 : 12, 1 : 1, 2 : 1, 3 : 1, 4 : 1, and up to 8 : 1, 40 : 1
,, *kodo* millet, 3 : 1
,, *Panicum miliaceum*, 1 : 5

Legumes

Jowar to red gram, 1 : 1, 2 : 1, 3 : 1, 4 : 1, 5 : 1, 6 : 1, 7 : 4, 10 : 1, 17 : 3
,, field beans, 3 : 1, 4 : 1, 10 : 1

Jowar to black gram, 1 : 1, 2 : 1, 3 : 1, 4 : 1, 5 : 1, 5 : 3, 5 : 4, 12 : 5, 17 : 3
,, green gram, 1 : 1, 3 : 1, 4 : 1, 6 : 1, 10 : 1, 12 : 1, 17 : 3, 5 : [illegible]
,, Bengal gram, 4 : 1, 5 : 1
,, horse gram, 1 : 1, 2 : 1, 3 : 1
,, cowpeas, 1 : 1, 2 : 1, 3 : 1
,, cluster beans, 1 : 1, 2 : 1, 3 : 1, 4 : 1, 5 : 1
,, *matki*, 1 : 1, 2 : 1, 3 : 1, 4 : 1, 6 : 1, 4 : 5, 15 : 1, 20 : 1
,, groundnuts, 1 : 5 and up to 1 : 15, 1 : 28
,, sannhemp, 4 : 5, 3 : 1
,, indigo, 5 : 2
,, *methi*, 15 : 2

Others

Jowar to cotton, 1 : 9, 1 : 1, 1 : 4, 3 : 8
,, *gingelli*, 12 : 1, 9 : 1
,, safflower, 3 : 1, 5 : 1, 8 : 1
,, castor, 3 : 1
,, Deccan hemp, 6 : 1, 19 : 1
,, mustard, 3 : 1
,, water melons, 2 : 1, 50 : 1

The proportions given are the proportions of the seeds by weight.

Bajri

Bajri is one of the major grain crops of India. It is grown throughout the country with the notable exceptions however of Bengal, Bihar and Assam among the important provinces. It is a grain crop almost exclusively of the *kharif* season, and is largely a rainfed crop. It is grown mostly on the red, loams and sandy loams, of the large stretches of the Gangetic alluvium ; the coarser and somewhat poor soils are put under this crop. Black cotton soils and heavy soils, and the deeper and better class soils generally are exceptional and are generally reserved for *jowar* and wheat. Even when the black cotton soils are sown with this crop it is only the medium and lower grades, light in colour and of little depth that are given over to *bajri*. Though mainly a rainfed crop, irrigation is also practised, especially in the Punjab.

The crops grown in mixture with *bajri* numbering 20 in all are the following :

Cereals

Ragi
Italian millet
Maize
Jowar (principally as fodder)

Pulses

Red gram
Black grem
Field beans
Green gram
Horsegram
Cowpeas
Cluster beans
Matki
Sannhemp

Others

Castor
Gingelli
Groundnut
Indigo
Gingelli
Cotton
Water melons

The absence of the following from the list of mixed crops is worthy of note thus rice, kodo millet, *Panicum miliare*, *Panicum miliacum* among the cereals, Bengal gram among the pulses and among the crops of other categories the crops of the mustard group.

The exclusion is due to the seasonal unsuitability in some but in other it cannot be said whether it is a case of incompatibility and if so what the reason may be.

The mixtures consist as in the case of the others of either single crop or two crops or more crops. The Table X gives the information classified according to their number and composition :

TABLE X

Mixtures of ragi

—	Cereals	Legumes	Others
With one crop	*Jowar* do. (fodder) Maize Italian millet *Ragi*	*Matki* Horse gram Red gram Cluster beans Black gram Green gram Cowpeas Sannhemp	Cotton Ground nuts Gingelli Deccan hemp Water melons

TABLE X—*contd.*

Mixtures of ragi—contd.

——	Cereals	Legumes	Others
With two crops	*Jowar*	Red gram	
	Italian millet	Groundnuts	
	Jowar	Groundnuts	
		Red gram	Castor
		Green gram and black gram	
		Green gram and *matki*	
		Black gram and clusterbeans	
		Red gram and groundnuts	
		Cowpeas	Deccan hemp
		Cowpeas	Indigo
With more than two crops	*Jowar*	Red gram, groundnuts	
		Red gram, cowpeas	
			Cotton, gingelli
		Red gram, green gram, sannhemp, cow peas	Deccan hemp, cucumber
		Field beans, cowpeas	
	Ragi		
		Red gram, black gram, *Matki*, cow peas	Gingelli
		Red gram, cluster beans, black gram, green gram	
		Black gram, green gram, cow peas	
		Horse gram, *matki*, black gram	
		Red gram, green gram, cowpeas, *matki*	
		Cluster beans, black gram, *matki*	

The mixtures reported from the different provinces number 39 in all, cereals enter into 13, pulses into 29, and other crops into 11 mixtures.

Proportion of the components, Where mixtures are composed of *bajri* and one other crop, the proportion of *bajri* to the latter vary a good deal, and the range of these variations is as given below :

(*a*) *Cereals. Bajri* and *jowar* are as from 1 : 1 to 1 : 8, and also 12 : 1 mostly as fodder *jowar* in the Punjab. *Bajri* to Italian millet varies from 1 : 3 to 1 : 10 (Madras).

(*b*) *Pulses.* A large variety of pulses is grown with *bajri*, and in many parts of the country the pulses are mixed together and sown in the rows; in parts of Bombay both pulses and *bajri* are mixed and sown in rows. Taking only such pulses as are grown as single crops with *bajri*, red gram is the commonest and the proportions are *bajri* to red gram is as 1 : 1 and 1 : 2 (Madras), 5 : 1 and 2 : 1 (Hyderabad), 5 : 1 (Bombay) and 1 : 1, 2 : 1, 3 : 1 and 4 : 1 (U. P.). *Bajri* with green gram varies in proportions from 1 : 1 to 4 : 1 ; with black gram from 1 : 1 to 1 : 8, and in one case is as 3 : 1 (U. P.). *Bajri* with cowpeas is as 3 : 1 and as 10 : 7, with *matki* as 1 : 1, 1 : 10, 5 : 1 and 4 : 3, and with karum *payaru* as 1 : 1.

(c) *Other crops.* These consist of groundnut, gingelli, cotton and Deccan hemp (*gogu*) ; and the respective proportions are as below :

Bajri with groundnut—1 : 26 (Madras)

do. gingelli—3 : 1 (Madras), 5 : 1 and 7 : 3 (U. P.)

do. cotton—4 : 1 and 2 : 1 (Madras and Punjab)

do. Deccanhemp —4 : 1 (Madras)

The proportions are all of seeds by weight.

Ragi

This grain crop is almost entirely a South Indian crop and is confined to the Madras Province and the Mysore State. To a very small extent it is cultivated also in the Bombay Presidency, Hyderabad, Bihar and in the Rajputana States.

It is a typically red soil crop, the red and light red loams characteristic of the most parts of Southern India form the most important if not the only soils on which it is grown. The crop can and sometimes is grown on the black cotton soils and on the black somewhat clayey soils under tank irrigation, but compared with the red soil cultivation, these are negligible.

The crop is confined to the *kharif* season and in the Mysore State where it is a very important crop and forms the staple food crop of the bulk of the people, it is grown almost entirely as a rainfed crop. In the Madras Province very extensively (if not universally) and in Mysore to a small extent, it is grown under irrigation.

As a rainfed crop in Mysore it is grown almost invariably with one or more mixed crops, though there are exceptions, such as where it is transplanted or in the case of the early sown crops. In Madras however even under irrigated cultivation, and also irrespective of the method of cultivation, broad-cast of transplanted, mixtures are almost the rule, and a very large number of crops are made use of for this purpose.

The crops which are grown in mixture with *ragi* numbering 24 in all are the following :

Cereals

- Wheat
- Italian millet
- *Jowar*
- *Panicum crusgalli*
- Maize
- *Save* (*Panicum miliare*)
- *Bajri*

Pulses

- Red gram
- Field bean

Black gram
Green gram
Horse gram
Sannhemp
Cowpeas

Others

Castor
Niger
Groundnut
Gingelli
Linseed
Deccan hemp
Mustard
Cotton
Amaranthus
Vegetables

The large variety of crops grown in mixture with *ragi* is noteworthy. The reason is principally the great importance of the crop as a food crop and the fact that nearly every cultivator grows it in the tracts concerned. The large variety of crops required in addition for the domestic use or petty trade of each person is therefore raised along with this food crop. Even where the main crop is groundnut or cotton, the importance of the *ragi* crop induces the grower to cultivate a little *ragi* also, even though it may be only a small percentage with the main crop.

This large variety of mixed crops, it will be seen, includes cereals, pulses, oilseeds, fibre crops, and vegetables, includes shallow-rooted crops and deep-rooted crops, short bushy low growing crops, tall and very deep-rooted crops, crops of short duration maturing before or simultaneously with *ragi*, crops of long duration maturing some two or three months after the *ragi*, tall crops with little or no branching and tall many branched bushy crops with a deep root system. Some of the crops are also such that they can flourish and make use of the heavy dews of the months of December and January, while the deep-rooted ones can thrive with the soil moisture in the deeper layers. The *ragi* crop itself is remarkably drought resisting and has the property of recovering from a long spell of drought in a striking manner, all of which are factors in making it a suitable crop in mixed cropping.

It will be seen that among the pulses Bengal gram does not figure, nor the oilseeds, linseed and safflower, cotton too is somewhat exceptional. These are crops pre-eminently of the black cotton soil, and partly also of the *rabi* or late season, which features will explain their exclusion. It cannot be said if they are incompatible with *ragi* and if so what the reason may be. On the whole *ragi* may be said to possess a wide range of compatibility.

The mixtures with *ragi* consist of single crops or of more crops. In the Table XI all the mixtures reported are classified into three classes, those with one, with two and with more than two crops with *ragi*.

TABLE XI

Mixtures of ragi

——	Cereals	Legumes	Others
With one crop	Wheat Italian millet *Panicum crusgalli* Maize *Jowar*	Red gram Field bean Black gram Green gram Horse gram Cowpeas Groundnuts Sannhemp	Cotton Mustard Niger Castor Gingelli Deccan hemp Amarnthus
With two crops	*Jowar*	Field beans Cowpeas and field beans Red gram Sannhemp	Deccan hemp Gingelli Cotton and castor
With more than two crops	*Bajri* *Jowar*, rice and Italian millet	Field beans and cowpeas Black gram, red gram	Deccan hemp Castor Deccan hemp and vegetables

The total number of mixtures reported amount to 27 in all. Of these cereal enter into nine mixtures, pulses into 13 and other crops into 13 mixtures.

Proportions in mixtures—In most of the mixtures *ragi* is the main crop and therefore occupies the larger portion of the area. Even where the *ragi* comes in as a subordinate crop as in the case of groundnuts it occupies a larger area than may be considered usual in such cases. Taking the mixtures composed of *ragi* with one other crop the following proportions are reported :

(*a*) *Cereals*

Ragi with *jowar*, 70 : 30
do. Italian millet, 1 : 2
do. Wheat 3 : 1
do. ooda (*Panicum crusgalli*) 6 : 1

(*b*) *Pulses*

Ragi with field beans 12 : 1, 6 : 1, 4 : 1, 4 : 1
do. redgram 5 : 2, 4 : 2, 4 : 3, 5 : 3

Ragi with	green gram 6 : 1
do.	black gram 3 : 1, 6 : 1, 2 : 1
do.	horse gram 6 : 1
do.	cow peas, 3 : 1, 6 : 1, 4 : 1, 5 : 1
do.	sann hemp, 6 : 1

(*c*) *Other crops*

Ragi with	cotton, 3 : 2, 1 : 2
do.	castor, 4 : 3
do.	gingelli, 3 : 1
do.	linseed, 5 : 1
do.	ground-nut, 3 : 40, 1 : 38
do.	indigo, 3 : 1
do.	niger, 12 : 1
do.	mustard, 16 : 1
do.	Deccan hemp, 6 : 1

The proportions are all of seeds by weight.

For proportions in mixtures of more than crop with *ragi vide* appendix.

The crop it will be seen is grown both as a main crop as well as a subsidiary crop, however small this may be, and with almost every kind of crop. Thus while as a main crop it may occupy 12 or even 16 rows for every one row of a mixed crop, it may itself as a subordinate crop occupy only one row out of 40 rows as in the case of ground-nuts.

WHEAT

Wheat forms an important cereal crop only in North India and in Peninsular India north of the river Krishna. The cultivation is confined to the *rabi* season, but in respect of soils there is a large variety such as the black cotton soils of different grades, the light and heavy loams of the Gangetic alluvium and fertile garden loams. The crop is grown both as a dry or rainfed crop and also under irrigation. The crops which are mixed with it are various; they differ according as the wheat is grown on black cotton soils as a dry crop or the light and heavy loams under irrigation. These crops numbering 12 in all consist of the following :

Cereals
- Barley
- *Jowar*
- Coarse rice (*sathri*)
- *Ragi*

Pulses
- Gram (Bengal gram)
- Wild peas

Others

Mustard
Rape
Sarson
Turnips
Safflower
Linseed

It will be seen that as compared with other main crops wheat has only a small number of mixed crops. The fact that the season viz., *rabi*, is short as compared with the *kharif* and that the hot weather follows upon it closely, with its intense drying action upon the soil moisture, only crops of short duration, practically about 100 days or less, can be grown.

Among the mixed crops listed above, barley is the most important among cereals and the others, viz., *ragi*, rice and *jowar* are of very minor importance. Likewise among the pulses, gram is not only the commonest and the most important but is almost the only pulse crop mixed with it. Among the other crops linseed is the most important one with safflower as a very minor crop, except in parts of Bombay and Hyderabad ; the mustard and its allied crops are very common and almost invariable mixtures, prevalent throughout Upper India from the N. W. F. Province in the west to Assam in the east.

The various mixtures classified according as they contain one crop, two crops and more than two, along with wheat are given below :

TABLE XII

Mixtures of wheat

—	Cereals	Legumes	Others
With one crop	Barley *Jowar* *Ragi* *Sathri* (coarse rice)	Bengal gram Wild peas	Linseed Safflower Rape Mustard Turnips
With two crops	Barley Barley Barley	Bengal gram Bengal gram Bengal gram Bengal gram	 Mustard Rape Linseed Mustard Rape
With more than two crops	Barley *Ragi*, Italian millet	Bengal gram Bengal gram Bengal gram	Mustard Onions and Cambodia cotton Mustard and safflower Linseed and mustard

The total number of mixtures reported amounts to only 21 on the whole, of these 9 contain cereals, 9 contain pulses and 14 contain crops of other kinds.

Proportions in mixtures. The proportion of the components in the crop mixtures which contain wheat and one other crop does not show the same very wide variation as in the case of other main crops. The barley and gram form important components in these two crop mixtures. The following are the proportions in respect of these crop mixtures :

Cereals

Wheat to barley, 1 : 1, 2 : 1, 3 : 1, 4 : 1, and 6 : 1

Pulses

Wheat to gram, 1 : 1, 2 : 1, 10 : 1 (Hyderabad)
1 : 1, 1 : 1½, 1 : 2 (Bengal)
1 : 1, 2 : 1, 3 : 1, 4 : 1 (Punjab)
1 : 1, 2 : 1 (Assam)
4 : 3 (Bhopal)
1 : 4 (Bombay)
1 : 1 to 6 : 1 (in the U. P.)
do. berseem, 1 : 1
do. safflower, 10 : 1, 15 : 1, 6 : 1 and 7 : 1

Other crops

Wheat to linseed 9 : 1 and 15 : 1 (U. P.)
do. mustard and allied crops. 1 : 1, 4 : 1, 10 : 1, 40 : 1, 50 : 1 and even insignificant ones like 170 : 1 and 240 : 1

The proportions are all of seeds by weight.

Barley

Barley is an important grain crop only in the region north of the Vindhya mountains in the great Gangetic plains of Upper India. The United Provinces are the most important in this respect and the Punjab, North West Frontier Province, and Bihar come next while in Bengal and Assam it figures to a moderate extent.

Barley is a crop of the *rabi* season like wheat. With regard to soils the great bulk are the light loams, unlike wheat which is very important on the heavy black cotton type of soils, though to a large extent it is grown on the light loams also like barley. The crops which are grown as mixed crops with barley are not very numerous, which is rather noteworthy, as compared to other crops. The crops which form mixtures with barley numbering 14 in all are the following :

Cereals

Wheat

Pulses

Red gram
Bengal gram

Pulses—contd.

Lentils
Peas
Berseem, *shaftal*
Senji

Other crops

Linseed
Mustard
Rape
Sarson
Cereal

It will be seen that wheat is the only cereal crop grown with it, that the large number of minor pulses which usually comprise a pulse mixture green gram, black gram, cow peas, *matki*, etc., are absent. Lentils and peas which are practically Upper Indian crops are the pulses grown in addition to red gram and Bengal gram. As compared with wheat it is to be noted that red gram is grown with barley while it is not seen in any of the wheat mixtures.

Among the crops other than the cereals and pulses, there is a striking lack of variety, linseed and the different mustards being the only two kinds grown. On the whole barley is peculiar in the fact that so few crops enter into mixtures with it.

In the Table XIII, the mixtures are classified into mixtures comprising one crop, two crops and more than two crops with barley :

TABLE XIII

Mixtures of barley

—	Cereals	Legumes	Others
With one crop	Wheat	Red gram Bengal gram Lentils Peas Berseem *Shaftal* *Senji*	Mustard Linseed *Sarson*
With two crops	Wheat	Bengal gram	*Sarson*
		Peas and Lentils	
		Peas, Bengal gram	Mustard
		Peas, Bengal gram	Mustard and linseed
			Mustard
	Wheat	Lentils	Rape
	Wheat	Lentils	Mustard
		Bengal gram	Rape
With more than two crops	Wheat Wheat	Bengal gram Peas, Lentils Peas, Bengal gram	*Sarson* Mustard Mustard and linseed

The total number of mixtures reported amount to 16 in all. Out of these five mixtures contain cereals either singly or in mixture, 13 contain pulses, and 10 contain the others, either singly or in mixture.

Proportions of the components. The proportions of the components in the mixtures in which one other crop forms the mixture with barley are as shown below :

Cereals

Barley to wheat 1 : 1, 1 : 2, 1 : 3, 1 : 6, 6 : 5, 9 : 1

Legumes

Barley to Bengal gram, 1 : 1, 1 : 3, 2 : 3, 2 : 1, 3 : 1, 7 : 3, 15 : 1

do. lentils 1 : 1, 2 : 1, 3 : 1, 6 : 1, 17 : 1, 1 : 1, 99 : 1, 2 : 3 (1 : 1 is very common in U. P.).

do. peas, 1 : 1, 1 : 2, 2 : 1, 3 : 1, 4 : 3, 3 : 2

do. *senji*, 1 : 1, 1 : 5

do. *shaftal* 1 : 1

Others

Barley to *sarson* or mustard 9 : 1, 49 : 1, 50 : 1, 40 : 1

do. linseed, 10 : 1

The proportions are of seeds by weight.

Maize

As an important grain crop grown on a field scale maize assumes much importance only in Upper India ; the Punjab, the North West Frontier Province, North Bihar, Bengal and Assam may be taken as the main areas of cultivation on a large scale ; elsewhere it is more or less a garden crop of minor importance. The crop is grown as a mixed crop both as a rainfed crop and under irrigation. It is grown both in the *kharif* and in the *rabi* season. The crops which are grown in mixture with maize numbering 26 in all are the following :

Cereals

Rice (dryland)

Bajri

Italian millet

Sanwak (*Panicum colonum*)

Ragi

Jowar

Pulses

Green gram

Matki

Pulses—contd.

Cow peas
Matikalai
Red gram
Cluster beans
Berseem (*shaftal*)
Soyabeans

Other crops

Sarson
Turnips
Cotton
Castor
Sugarcane
Potatoes
Gingelli
Jute
Ground-nuts
Vegetables

The important grain crops of Upper India, viz., wheat and barley are not listed among the mixed crops nor even *jowar*, except as a border crop, raised apparently for fodder purposes. Among the pulses horse gram is not listed and even Bengal gram figures only to a very small extent. Linseed the important *rabi* season oilseed crop is likewise conspicuous by it absence.

Proportions of the mixtures. Taking the case of the mixed crops which are grown as ~~the only mixed crop with~~ maize, the proportions of the mixtures are reported as follows :

Cereals

Maize to rice (dryland), 5 : 1
do. *ragi*, 1 : 1
do. Italian millet, 1 : 3
do. *bajra*, 6 : 1
do. sanwak, 16 : 1
do. *jowar*, 1: 3

Pulses

Maize to cow peas, 5 : 4, 4 : 1, 2 : 1
do. black gram (*mush*), 2 : 1, 1 : 1, 5 : 2, 3 : 1, 5 : 1
do. green gram (*mung*), 2 : 1

Maize to gram, 1 : 1
do. berseem, 12 : 1
do. cluster beans, 3 : 2
do. red gram, 2 : 1, 4 : 1
do. soyabeans, 1 : 4

Other crops

Maize to turnips, 18 : 1
do. *sarson*, 8 : 1, 1 : 1
do. sugarcane, 1 : 20
do. turmeric, 1 : 4
do. garlic, 1 : 1
do. ground-nuts, 1 : 1
do. cotton, 1 : 5, 3 : 4

The proportions are all of seeds by weight.

In the Table XIV, the mixtures are classified into mixtures of maize with one crop, two crops and with more than two crops.

TABLE XIV

Mixtures of maize

—	Cereals	Legumes	Others
With one crop	*Bajri* Rice *Jowar* *Ragi* Italian millet *Panicum colonum*	Black gram *Matki* Bengal gram Berseem Soya beans Cow peas Red gram Cluster beans	Cotton Sugarcane Garlic *Sarson* Turnips Turmeric Potatoes
With two crops	*Jowar*	Red gram	
	Rice	Black gram	
		Red gram	
		Red gram	Cotton
			Gingelli
		Black gram and green gram	
With more than two crops	Rice, *jowar*	Black gram	Jute
	Italian millet		Melons
	do.	Green gram	
	Panicum crusgalli	Red gram	Cotton and castor
		Black gram, green gram and cow peas	Mixed vegetables

The number of mixtures reported amounts to 32 in all. Of these 11 contain cereals, 17 contain pulses and 13 contain other crops.

COTTON

This most important crop next to food crops is grown practically throughout India, with however some notable exceptions. It does not figure among the crops reported from Bengal and the North West Frontier Province and in Bihar and Assam it appears to be of only very minor importance.

The typical so called black cotton soils form the large bulk of cotton soils, throughout the country except in the Gangetic plain where the alluvial loams which are the prevailing type are put under cotton also. In South India there is a certain amount of specific preference of the black cotton soils for the local cotton varieties and of the red, reddish loamy or coarse soils for the American cottons. One indigenous cotton however is generally grown on the red soil and even coarse gravelly soils, viz., the *roseum* cotton.

Cotton is grown largely as a rain fed crop. The bulk of the indigenous cotton is grown only on the black cotton soils, and on these soils the cotton is grown only as a rainfed crop. Practically all the South Indian grown American cotton which comprises a good deal of the Dharwar American cottons of Southern Bombay, Mysore and Madras is also grown as a rainfed crop. The Cambodia cotton of Madras is almost entirely grown under irrigation like a garden crop. In the Punjab and the United Provinces cotton both American and even local, is grown largely under irrigation.

Cotton is grown both as a pure crop and with mixtures of one or more crops. As in the case of all the other crops it is difficult to say what the respective proportions of pure and mixed cultivation may be. As in the case of soils and irrigation, there is a certain preference for one or other method according to the variety grown; the Dharwar American cottons in Mysore, Southern Bombay and some other tracts is grown mostly pure, while mixtures are largely practiced in these tracts only in the case of the local cottons. The case of the Cambodia cotton is however different, many minor garden crops and others being grown in mixture especially along the margins, water channels, etc. The crops which are grown in mixture with cotton numbering 22 in all are the following:

Cereals

- Rice
- *Ragi*
- Italian millet
- *Bajri*
- *Jowar*
- Maize
- *Kodo millet*

Pulses

Red gram
Black gram
Green gram
Horse gram
Matki
Cow peas

Other crops

Cotton (*desi* or American)
Ground-nuts
Gingelli
Castor
Deccan hemp
Chillies
Bhendi
Sarson
Melons

The crops which are conspicuous by their absence in the above list are wheat and barley among the cereals, Bengal gram among the pulses and linseed among the other crops. All these it will be noted are *rabi* season crops while cotton is *kharif* sown crop, though sometimes the sowing may be so late as to be almost at the beginning of *rabi*.

The mixed crops are sown either singly with cotton or two or more of them enter the mixture. The various mixtures reported are classified in the Table XV into mixtures containing one mixed crop, two mixed crops and those with more than two.

TABLE XV

Mixtures of cotton

—	Cereals	Legumes	Others
With one crop	*Ragi* Italian millet Rice *Bajri* Kodo millet *Jowar* Maize	Black gram Horse gram Cow peas Red gram Green gram Cluster beans Ground-nuts Sann hemp	Coriander Gingelli Chillies Safflower Deccan hemp Melons *Sarson* Cotton, *desi* and American *Niger* Castor *Bhendi*

TABLE XV—*contd.*

Mixtures of cotton—contd.

——	Cereals	Legumes.	Others.
With two crops	*Ragi*		Castor
	Rice	Red gram	
	Jowar	Horse gram	
		Ground-nuts	Gingelli
		Horse gram	*Niger*
		Cow peas and black gram	
		Black gram and green gram	
		Red gram and ground-nuts	
			Niger and Deccan hemp
			Gingelli and amarnt
With more than two crops	Italian millet, wheat		Coriander
	Ragi, wheat, Italian millet		Onions
	Jowar, *bajri*		Gingelli
	Jowar	Horse gram, cow peas	Deccan hemp
	Italian millet	Black gram	Gingelli and *tinda*
	Maize	Red gram	Castor
	Kodo millet	Red gram	Gingelli and Deccan hemp
	do. rice	Cluster beans, red gram and cow peas	
		Field beans, cow peas, ground-nuts	
		Red gram, black gram and green gram	Coriander
		Cluster beans, cow peas	Deccan hemp
		Black gram	
		Red gram, cluster bean and black gram	Gingelli, *tinda* and *bhendi*
		Black gram, green gram	Gingelli

The total number of mixtures reported comprise 51 in all, which is very much larger than the number of mixtures for many other crops. Among these 18 mixtures contain cereals, 26 contain pulses and 31 contain other crops also. Italian millet is perhaps the most important among the mixed crops with cotton.

Among the mixtures reported one of the most interesting is the mixture of *desi* (indigenous) and American cottons which is said to prevail in the Punjab. It is well known that the lack of purity in the cotton marketed in India is greatly condemned and much propaganda is carried on for ensuring such purity and the avoidance of all causes by which such mixture may arise. That this kind of mixed sowing should take place and be carried out as a recognised practice in that province show that, the advantages of mixed sowing whatever they may be sufficiently outweigh in the estimation of cultivators those of maintaining purity in the crop, as to induce them to prefer the former course. It is however possible that the cotton from the two different varieties is gathered separately; we have no information on this point.

Such a special effort appears highly improbable, if one may judge from the general attitude of the ryot in such matters.

Attention may be drawn in this connection to the same kind of practice of sowing two varieties or types, which is said to prevail in the Malwa plateau and to which reference has already been made. Experiments reported by Mr. K. Ramiah, Geneticist, show that from a financial point of view such mixing is a distinct advantage.

The proportions in which any one single crop forms a mixture with cotton are as shown below :

Cereals

Rice, 1 : 4, 2 : 1, 1 : 1, 35 : 20, 40 : 35

Ragi, 1 : 6, 1 : 2, 2 : 1

Italian millet, 1 : 2, 1 : 1, 10 : 1, 2 : 1, 1 : 3

Bajri, 1 : 2, 1 : 1

Jowar, 10 : 1, 4 : 1, 1 : 1

Maize, 4 : 3, 5 : 1, 1 : 1, 6 : 1

Pulses

Red gram, 2 : 1, 15 : 2, 6 : 1, 3 : 1, 9 : 1, 12 : 1, 1 : 1

Black gram, 7 : 3, 7 : 1, 5 : 1

Green gram, 8 : 3, 7 : 1, 4 : 1

Matki, 2 : 1, 3 : 2, 5 : 1, 8 : 1

Horse gram, 5 : 8, 4 : 1, 1 : 1, 2 : 1, 3 : 1

Other crops

Cotton (*desi* and American), 1 : 10 to 10 : 1

Ground nuts, 3 : 40, 1 : 6, 1 : 5, 1 : 7

Gingelli, 8 : 2, 8 : 3, 20 : 1, 12 : 1, 5 : 1

Castor, 9 : 1

Deccan hemp, 9 : 1, 9 : 5

Chillies, 1 : 3, 32 : 1, 1 : 1

Bhendi, 8 : 3

Sarson, 3 : 1, 32 : 1, 20 : 1

Melon, 8 : 1

The proportions are all of seeds by weight.

Ground-nuts

Ground-nuts may be said to be almost solely a South Indian crop, some what like *ragi* among the cereals. It must be also considered a comparatively newly introduced

crop and the large and striking extension in the cultivation of the crop is certainly a matter of recent development, due to the large and profitable export demand which has been steadily on the increase for the last 30 or 40 years, with the exception of the period of the great war. For this reason unlike the many other crops which have been under cultivation for centuries in the case of this crop the general vogue of mixed cropping appears to have been taken up rather slowly and tentatively. The crop is grown as a pure crop to a much larger extent than any of the other dry-land (rainfed) crops. Other characteristics of the crop are such that they may be said to be favourable for mixed cropping in some respects and not favourable in other respects.

Firstly, the crop is of a low growing habit, the main variety is indeed only a creeping plant, and practically hugs the ground. The other type, viz., the so-called erect varieties, do not grow more than nine inches or a foot in height. This low growing habit is favourable to the growing of mixed crops of almost all kinds, as all of them grow taller and clear of the ground-nut crop. Secondly, the erect varieties are short duration crops of about three months or even less, so that many crops taking a longer period to mature lend themselves to be grown in mixture. Thirdly, the spreading varieties are of long duration taking five months to mature and therefore lend themselves to have short duration crops growing in their midst as mixed crops. On the other hand the spreading varieties cover the ground so completely and so thickly, specially under favourable conditions of rainfall and cultivation and the nuts form all along under the vines that conditions for mixed cropping are not favourable ; considerations of a full and economical utilisation of the soil which weigh in favour of mixed cropping, therefore do not arise. As the result, it may be said that for mixed cropping the short duration erect varieties are preferred to the long season creeping varieties. In fact in Mysore, it is rare to see mixed crops in the midst of these latter types at all.

The groundnut crop is grown as a rainy season (*kharif*) crop. It is grown both as a rainfed crop and as an irrigated crop, the former of course forming the bulk. The crop is largely grown in the light, very light and good loamy soils, mostly of the red lateritic type and the deep alluvial type ; the black cotton soils are also utilised but not to the same extent

Crops grown in mixture. Where mixed cropping is adopted a very large number of crops are made use of for the purpose. They number 17 in all and consist of the following :

Cereals

Bajri

Jowar

Ragi

Italian Millet

Cereals—contd.

Maize

Rice

Pulses

Red gram

Field gram

Cow peas

Black gram

Green gram

Horse gram

Other crops

Gingelli

Cotton

Castor

Deccan hemp

Coriander

It will be noticed that the typical *rabi* crops do not figure, as may be expected. Further, quite a number of leguminous crops also enter into the mixture notwithstanding the fact that the ground-nut itself belongs to the same order and that the mixture of legume and legume is not common. Attention may also be drawn to the fact that many crops with a low growing habit and some with a semi creeping habit also, like horse gram, green gram, black gram, coriander and cow peas and field bean also are made use of for mixtures. The domestic or other needs of individual cultivators apparently form a more important factor than considerations of strict suitability in deciding the choice of crops used for mixing.

In the Table XVI, the various mixtures are shown classified according as they contain one, two or more crops along with the ground-nuts.

TABLE XVI

Mixtures of ground-nuts

—	Cereals	Legumes	Others
With one crop	Italian millet *Ragi* *Bajri* Maize *Jowar*	Red gram Green gram Cow peas Horse gram	Gingelli Cotton Deccan hemp Castor Coriander
With two crops	*Jowar* *Jowar* *Bajri*	Field beans Red gram Red gram	

TABLE XVI—*contd.*

Mixtures of ground-nuts—contd.

—	Cereals	Legumes	Others
With two crops	*Bajri* and *jowar*		
	Maize	Black gram	
		Red gram	Gingelli
		Red gram and green gram	
		Red gram	Deccan hemp
			Castor and gingelli
With more than two crops	*Panicum crusgalli*	Field bean	Coriander
	Rice	Red gram, cow peas	Gingelli
	Rice	Red gram, cow peas	Castor
	Maize		Cotton and Deccan hemp
		Red gram, field bean	Castor

The total number of mixtures reported is 28. Out of these 14 have cereals 15 have pulses and 12 have the other crops also.

Proportion of crops in the mixture. The proportion in which the different crops are mixed in the mixtures which have only one mixed crop with ground-nuts are the following :

Cereals

Ragi, 80 : 6
Italian Millet, 70 : 2½, 9 : 1
Bajri, 60 : 4, 10 : 2, 80 : 3, 80 : 4
Maize, 80 : 20

Pulses

Red gram 9 : 1, 70 : 1, 75 : 2, 60 : 4, 7 : 1, 10 : 1, 6 : 1, 50 : 3, 25 : 2, 8: 1, 3 : 1, 7 : 1
Green gram 10 : 2

Other crops

Cow peas, 60 : 1
Gingelli, 95 : 5
Castor, 5 : 1
Cotton, 40 : 3, 10 : 2, 7 : 1
Deccan hemp, 10 : 2, 25 : 1
Coriander, 15 : 1, 20 : 4

The proportions are all of seeds by weight.

RED GRAM

Red gram may be regarded as both distinctive and important among mixed crops. It is seldom or never grown pure except on a very small scale and mixed cropping may be said to be the rule on a field scale. It forms one of the most important and extensively grown pulse crops of the country. With the exception of the N.W.F. Province, the Panjab in the north and Assam in the east, in all other

parts of the country viz., Madras and Bombay Presidencies, the Central Provinces and Berar the U.P., Bihar and Bengal, the Central Indian States, Hyderabad, Mysore grow the crop extensively. The western parts of peninsular India where the S.W. monsoon is very heavy, as likewise the north-eastern province like Assam where the rainfall is equally heavy, do not grow the crop, on this account. It is not clear why the crop does not figure in the Punjab where the rainfall is low and where it is insufficient can be supplemented by irrigation. In tracts where rainfed cultivation is alone possible and the cultivation season is only the *rabi* or north-east monsoon season, the season is too short for the crop and Bengal gram takes its place as the staple pulse crop. Red gram as a mixed crop is also noteworthy because it is grown in mixture with a large number of crops and the combinations are numerous. In the regions of its cultivation it may be called a universal favourite consorting with advantage with every crop under general cultivation.

The crop is grown as a *kharif* crop, but it occupies the ground through part of the *rabi* season also ; the crop season extends from June-July to February-March.

It is grown on all the different kinds of soils, the red soils of South India, the black cotton soils, the Gangetic alluvium and even rough gravely soils.

It is grown in mixture with one single crop, with two or more than two, which may go up to even six in number. They comprise cereals, legumes and crops of other kinds, as given below :

Cereals

Rice (dry or upland)
Jowar
Bajri
Ragi
Italian millet
Kodo millet
Maize

Legumes

Black gram
Green gram
Field beans
Cluster beans
Matki
Cow peas
Sann hemp
Lentils
Ground-nuts

It will be noticed that the typical *rabi* crops like wheat, barley, Bengal gram, safflour, linseed, rape, mustard, etc. do not find a place in the list.

The total number of mixtures listed from the different provinces and States is 65 of these 17 contain only one crop together with red gram ; 22 contain two and 26 contain more than two. Moreover cereals enter into 41 mixtures, pulses in 36 and ; others in 32. These are tabulated in a classified form below :

Table XVII

Mixtures of red gram

—	Cereals	Legumes	Others
With one crop	Rice	Black gram	Deccan hemp
	Jowar	Green gram	Gingelli
	Bajri	Field beans	Cotton
	Ragi	Cow peas	
	Italian millet	Ground-nuts	
	Kodo millet		
	Maize		
	Panicum miliaceum		
	Panicum miliare		
With two crops	*Jowar*	Ground-nuts	
	Bajri	Ground-nuts	
	Jowar, *bajri*		
	Jowar	Field beans	
	Rice		Cotton
	Jowar		Gingelli
	Jowar		Jute
	Jowar	Black gram	
	Jowar, maize		
	Jowar, kodo millet		
	Jowar, rice		
	Jowar	Cluster beans	
	Maize		Gingelli
	Maize		Cotton
	Maize	Black gram	
	Kodo millet	Cow peas	
	Italian millet	Cow peas	
		Ground-nuts	Castor
		Ground-nuts	Deccan hemp
		Black gram and green gram	
		Black gram	Deccan hemp
		Black gram	Cotton
With more than two crops	*Jowar*	Field beans	Gingelli, castor
	Jowar	*Matki*, green gram, cow peas	
	Jowar	Black gram, green gram	
	Jowar	do. do.	Gingelli
	Jowar	Masoor	Gingelli
	Jowar	Black gram	do. Deccan hemp
	Jowar, rice, *ragi* and Italian millet		do. do.
	Jowar	Cluster beans	Cotton
	Bajri	*Matki*, cow-peas and green gram	
	Bajri, *jowar*	Green gram, sann hemp and cow peas	Cucumbers
	Bajri	Black gram, green gram	
	Bajri	Black gram	Gingelli
	Ragi	Black gram	Castor
	Ragi, rice	Ground-nuts	Gingelli, castor

TABLE XVII—*contd.*

Mixtures of red gram—contd.

——	Cereals	Legumes	Others
	Maize		Cotton, castor
	Maize, Italian millet and *Pan. miliare*		Jute
	Kodo millet		Castor gingelli
	do.		Gingelli, Deccan
		Black gram green gram	Gingelli
	do.	do.	Castor, *bhendi*
		do. cluster beans	Cotton
		do. green gram	Cotton, Deccan hemp and gingelli
		Black gram	Cotton, Deccan hemp
	Panicum miliaceum		Cotton castor

Proportions of Components.

The proportions in which the seeds of the different components are mixed are also very varied. They are perhaps more numerous than in the case of many other crops. These proportions are given below in respect of the mixtures which contain one other crop in addition to red gram. For other mixtures the statements in the appendix may be consulted.

Cereals

Red gram with rice 1:2, 1:4, 1:5, 1:6, 3:4, 2:1, 2:5, 1:7, 1:12, 3:25 ;
Jowar: 1:2, 1:4, 1:5, 1:10, 3:10
Bajri 1:8, 1:9, 1:1, 1:2, 1:3, 1:5, 1:50
Ragi 1:2 ;1:5, 1:6, 3:4, 2:1, 2:5
Italian millet 1:5, 1:7, 3:5 ;
Maize 1:3, 1:4
Kodo millet 5:1, 1:15
Panicum miliaceum 1:8, 1:9, 2:3
Panicum miliare 1:7

Legumes.

Red gram to black gram 2:3, 1:2
Green gram 1:7, 2:3
Field beans 3:7
Cow peas 5:7
Ground-nut 1:6, 1:7, 1:8, 1:15, 1:35, 1:60, 1:70

Others

Red gram with cotton 1:3, 1:5, 1:8, 1:9, 1:10, 1:14, 1:19, 3:44
Gingelli 1:1, 1:2, 1:3, 1:10, 7:9
Deccan hemp. 5:1, 9:5

The porportions given are of seeds by weight

ITALIAN MILLET

Although as a rule the grain crops are mostly grown as main crops whether pure or with subordinate crops as mixture, the case of Italian millet is somewhat exceptional. It is grown more or less as a subordinate crop and in mixture with a main crop which is very often cotton. Where rainfall is favourable and the soil fertile and well prepared it is sometimes grown as a pure crop of the year ; under these conditions a better yielding variety in which the earheads are long and heavy and drooping with the weight of grain is grown and a good yield of grain is obtained. To grow it as a mixed crop is however the common practice and a hardier one though less yielding variety is chosen for this purpose, the chief advantage of mixed cropping viz., an insurance against bad seasons being secured thereby. The crop is largely grown in the Deccan and South India generally, although to a certain extent it figures in Upper India also.

It is grown on all kinds of soils, the red lateritic, the Gangetic alluvium and the black cotton soils, on which it is grown in mixture with cotton.

The season is kharif—

The crops with which it is grown in mixture number 21 and are the following :

Cereals

Rice
Jowar
Ragi
Bajri
Maize
Wheat
Panicum miliare

Legumes

Red gram
Black gram
Green gram
Groundnuts
Sann hemp
Cluster beans
Cow peas

Others

Cotton
Gingelli
Deccan hemp
Coriander
Onions
Castor
Niger

The mixtures are not large in number being only 20. They comprise as in the case of other crops those with one crop in addition to Italian millet, those with two and those with more than two. They are tabulated in a classified form in Table XVIII.

TABLE XVIII

Mixtures of Italian millet

—	Cereals	Legumes	Others
With one crop	Rice *Jowar* *Ragi* Maize	Red gram Black gram Green gram Ground nuts Sann hemp	Cotton
With two crops	*Jowar* *Jowar* *Bajri* Maize	Cow peas	Castor Niger Gingelli Cotton, gingelli
With more than two crops	Wheat *Ragi* *Jowar* Maize and *Panicum miliare* Rice, *ragi* and *jowar*	Cow peas, cluster beans Black gram Red gram	Cotton, coriander Cotton, onions Gingelli, Deccan hemp

Proportions. The proportions in which the components are mixed are as below (mixture with one crop in addition to Italian millet) :

Cereals

Italian millet to rice 3 : 2
do. *jowar* 1 : 1, 1 : 3 , 3 : 4, 40 : 1
do. *ragi* 1 : 2, 1 : 6
do. maize 3 : 1

Legumes

Italian millet to red gram 5 : 1, 2 : 1, 5 : 3
do. black gram 2 : 1
do. green gram 2 : 1
do. ground nuts 1 : 9, 1 : 5, 3 : 80
do. sann hemp 1 : 2

Others

cotton 1 : 2, 1 : 10, 2 : 5

The proportions are of seeds by weight.

In view of the shortage of grain during the last two years it has been attempted to raise the proportion of the Italian millet in the mixture and thereby to increase the acreage under the crop.

APPENDIX I

Glossary of vernacular and common names of crops with their botanical names

Alu	*Colocasia antiquorum*
Ambadi	*Hibiscus cannabinus*
Arahar	*Cajanus indicus*
Arhar	,, ,,
Arika	*Paspalum scrobiculatum*
Avare	*Dolickos lab-lab*
Bajri	*Pennisetum typhoideum*
Bavto	*Eleusine coracana*
Barley	*Hordeum vulgare*
Bengal gram	*Cicer arietinum*
Berseem	*Trifolium alexandrinum*
Bhendi	*Hibiscus esculentis*
Black gram	*Phaseolus mungo*
Cambu	*Pennisetum typhoideum*
Castor	*Ricinus communis*
Chari	*Andropogon sorghum*
Chatri	*Lathyrus sativus*
Chuali	*Amaranthus blitum*
Chavali	*Cynamopsis psorialioides*
Cheema	*Panicum miliaceum*
Chillies	*Capsicum annuum*
Coriander	*Coriandrum sativa*
Cotton	*Gossypium* spp.
Cluster bean	*Cyampsis psorialioides*
Deccan hemp	*Hibiscus cannabinus*
Dhania	*Coriandrum sativa*
Ganti	*Pennisetum typhoideum*
Gingelli	*Sesamum indicum*
Gogu	*Hibiscus cannabinus*
Gowar guar, guara	*Cyampsis psorialioides*
Gram	*Cicer arietinum*
Ground-nuts	*Arachis hypogea*

Ginger	*Zingiber officinale*
Green gram	*Phaseolus radiatus*
Horse gram	*Dolichos biflorus*
Jodal	*Avena sativa*
Jola	*Andropogon sorghum*
Jonna	,, ,,
Jowar	,, ,,
Juar	,, ,,
Jute	*Corchorus capsularis, C. olitorius*
Kakum	*Setaria italica*
Kalai	*Phaseolus mungo*
Kali rai	*Brassica nigra*
Kamni	*Phaseolus aconitifolius*
Kangani, kangni	*Setaria italica*
Kasi mati-kalai	*Phaseolus calcalatus*
Kesari	*Lathyrus sativus*
Kodo, kodon	*Setaria italica*
Kodo millet	,,
Korra	,,
Kudrum	*Hibiscus cannabinus*
Kumra	*Cucurbitus* spp.
Kusum	*Carthamus tinctorius*
Kuthuraivali	*Panicum crusgalli*, var. *frumentaccum*
Lobia	*Vigna catiang*
Linseed	*Linum utitatissimum*
Maize	*Zea mays*
Mandua	*Eleusie coracana*
Marua	,, ,,
Mash	*Phaseolus radiatus*
Massoor	*Lens esculenta*
Massar	,, ,,
Matar	*Pisum sativum*
Matki	*Phaseolus aconitifolius*
Methi, Meth	*Trigonella foenum graecum*
Methra	,, ,,

Moth, Mothi	*Phaseolus aconitifolius*
Mong	*Phaseolus radiatus*
Mug	,, ,,
Mung	,, ,,
Mustard	*Brassica nigra*
Melon	*Cucurbita melo*
Navane	*Setaria italica*
Nagli	*Eleusine coracana*
Niger	*Guizotia abyssinica*
Okra	*Hibiscus esculentis*
Onion	*Allium cepa*
Ooda	*Panicum crusgalli*
Patal	*Trichosanthes dioica*
Patson	*Hibiscus cannabinus*
Patwa	,, ,,
Peas	*Pisum arvense*
Pillipesara	*Phaseolus aconitifolius.*
Pundi	*Hibiscus cannabinus*
Ragi	*Eleusine coracana*
Rahar	*Cajanus indicus*
Rai	*Brassica juncea*
Rala	*Setaria italica*
Ramas	*Vigna catiang*
Ravan	,, ,,
Red gram	*Cajanus indicus*
Rice	*Oryza sativa*
Safflower	*Carthamus tinctorius*
Sajje, sajjalu	*Pennisetum typhoideum*
Sankukra	*Hibiscus cannabinus*
Sanai	*Crotalaria juncea*
Sann hemp	,, ,,
Sanwak	*Panicum colonum*
Sarson	*Brassica napis*
Sathra	*Oryza sativa*
Sawan	*Panicum frumentaceum*

Senji	*Mellilotus parviflora*
Shaftal	*Trifolium resupinatum*
Sheria	*Hibiscus cannabinus*
Sesamum	*Sesamum indicum*
Sugarcane	*Saccharum officinarum*
Suran	*Amorphophallus campanulatus*
Swank	*Panicum colonum*
Save	*Panicum miliare*
Taramira	*Eruca sativa*
Teora	*Lathyrus sativa*
Tenai	*Setaria italica*
Tinda	*Citrus vulgaris*
Togari	*Cajanus indicus*
Tori	*Brassica napus*
Tur	*Cajanus indicus*
Tuver	,, ,,
Turmeric	*Curcuma longa*
Urid, Urd, udid	*Phaseolus mungo*
Val	*Dolichos lab-lab.*
Variga	*Panicum miliaceum*
Varagu	,, ,,
Wheat	*Triticum sativum*
Yam	*Dioscorea sativa*

APPENDIX II

Summary of results of mixed-cropping experiments in Madras Presidency

Station	Components of the mixture	Results
Coimbatore (cotton breeding station)	Pulses in combination with sorghum in different proportions in three different soils (irrigated red, rainfed red and rainfed black)	The mixing of pulse with both irrigated and rainfed sorghums did not benefit either the sorghum or the succeeding cotton ; on the other hand mixing lowered the straw weight

Station	Components of the mixture	Results
Coimbatore	Cotton mixed with *setaria*, horsegram and Coriander	Pure Cotton best but of the mixtures, cotton and *setaria* combination best. With cotton at normal price it would not be profitable to grow any mixture, though the demand for grain and fodder may make it useful.
	Mixtures of lab-lab and castor compared with pure castor in rotation with sorghum	Castor best as pure crop
Guntur	Pillipeasara with sorghum for fodder	No increase in yield of fodder
	Cotton with groundnut and setaria	Cotton and groundnuts gave the best monetary return followed by cotton and *setaria*, pure cotton resulting in a loss
Hagari	Cotton and setaria . .	Earlier experiments showed mixture is more economical than cotton alone but subsequent experiment disproved this showing that pure cotton, is economically the best
	Pulses with setaria . .	More economic than pure *setaria*. Of the pulses groundnut horse gram and *pillipesara*, groundnuts gave the best result
	Mixtures of sorghum and Bengal gram, sorghum and groundnut	Results not consistent
Kovilpatti	After-effects of a mixture (black gram and green gram in combination with sorghum) on the succeeding cotton	The harmful effects of sorghum not reduced by the mixed cropping
	Bengal gram, coriander and horse gram mixed with cotton	Monetary values of all the mixtures were less than that of pure cotton

Station	Components of the mixture	Results
Nandyal	*Pillepesara* with sorghum .	Depressing effect on the yield of sorghum. Pure sorghum best
	Sorghum with black gram, green gram and horse gram, cotton with horse gram	In the mixtures sorghum with horse gram the best combination. No difference in total outturn whether cotton grown pure or mixed with horse gram.
Palur	Groundnut inter-planted in a cereal	More advantageous than a groundnut-cereal rotation. Of the cereals, *ragi* proved to be best mixed with groundnuts.
		Change in the cereal had a better effect on the yields of groundnut and cereal than when the same cereal was repeated every year.
Tindivanam	Groundnut with *sorghum* cumbu, *setaria*, red gram castor	Monetary return was more from a mixed crop than pure groundnut crop, though the yield of groundnut was lower. Except *Setaria* or cumbu, all the others gave the better returns (monetary) than pure cropping.

APPENDIX III

Some selected rotations in the different provinces

1. North West Frontier Province

1. Maize—wheat—maize
2. Rice—*shaftal*—maize
3. Maize—tobacco—maize
4. Wheat—fallow—wheat
5. Wheat—cotton—wheat
6. Maize—berseem—maize
7. Maize—fallow—maize

8. Maize—*moth*—wheat
9. Maize—lentil—maize
10. Peas—fallow—peas
11. Rice—wheat—rice
12. *Shaftal*—sugarcane (ratooned for three years)—wheat
13. Gram—*bajra*—gram
14. Gram—*bajra*—*toria*
15. Barley—fallow—gram
16. *Toria*—maize—*toria*, etc.

2. *Bihar-Bhagalpur Range*

For single cropped—' Diara ' and ' Chaur ' lands (inundated during rains) paddy land.

For double cropped.—

For single cropped—' Diara ' and ' Chaur ' which get flooded sometimes early in the season and sometimes late.

The cultivators generally put in a crop of maize or millets like *khari* and *chena* during the *kharif* if they get early rains. In years the floods are late they get a crop, otherwise the crop is destroyed. In *rabi* wheat, gram, barley, peas etc., are rarely grown singly.

In paddy lands, paddy is followed by paddy in next year. In favourable years and in a restricted number of plots, peas, linseed, or *khasari* are sown broadcast on the standing crop. In rare cases paddy plot is cultivated and a *rabi* crop is grown with irrigation.

Double cropped lands (not subject to innudation)

(*a*) Maize or *juar* (for fodder) followed by *rabi* cereals, pulses, oilseeds like mustard and linseed, tobacco and chillies. The local practice is to sow the *rabi* crop in mixtures.

(*b*) Maize and *jowar* sown with *rahar maize* and *jowar* is harvested in September October and *rahar* stands till March.

In Purnea District where jute is grown the rotations are :
Lowland jute followed by paddy or lowland jute—first year, second year paddy. Because in many lowland jute plots the standing water remains so high after harvest that no transplantation is possible (small percentage of lands).

3. *Bhopal*

The general practice is to sow cotton or *jowar* after wheat, followed by gram.

4. *Bihar-Chota Nagpur Range*

It may be noted that these rotations are not rigidly adopted and mixed cropping is not very much in vouge in this tract.

PADDY LANDS

Kharif	*Rabi*
First year paddy broadcasted	Fallow or gram (*Cicer arietinum*) Wheat, moong (*Phaseolus mungo*) Linseed or *khesari lathyrus sativlus* as *paira* crop
Second year paddy transplated	do. do.

UPLANDS

Kharif	*Rabi*
First year— *Ragi* (*Eleusine coracana*) *Urid* (*Phaseolus eadiatus*) *Rahar* (*Cajanus indicus*)	Rahar and fallow
Second year—Paddy (*gora*), one of the early ripening variety	Fallow
Third year—*Urid*	Fallow
Fourth year— *Gundali* (small millets) *Kulthi* (*Dolichos biflorus*) *Surgura* (oilseed)	Fallow
First year—*Aus* paddy	Sugarcane
Second year—Sugarcane	Sugarcane

No definite rotations are followed in the case of maize, *jowar*, wheat, gram, barley, groundnut. They are grown in the same field year after year as follows :

(i) First year	Maize or *juar* with *sanai* or kudrum
(ii) First year—fallow or paddy	Wheat mixed with barley
(iii) First year fallow or paddy	Gram mixed with barley and linseed
(iv) First year—groundnuts	Fallow

5. *Patna Range*

Paddy is the principal crop grown ; the most general rotation is :

Paddy—*kesari*, or *kesari* and linseed mixed, or gram sown in standing crop of paddy.

The area of land which does not grow paddy is comparatively small and is confined to upland or some medium land. On such land if irrigable the rotations are :

Maize or *marua* or fallows —Potato or other vegetables or chillies.

If such medium lands are not irrigable, the general rotation is maize and *rahar*—

Udid mixed wheat and gram or barley and gram.

6. *Tirhut Range*

Low land—Paddy land

Paddy is grown year after year in the same land, and no rotation is taken. But at places where water remains in the fields when the grains reach the milk stage broadcasted crops like gram, peas and *khasari* are taken in the paddy fields. In a few cases linseed is also broadcasted.

UPLANDS

——	*Kharif*	*Rabi*
Rotation I—		
First year	Maize or mixture of millets	Sugarcane
Second year	Sugarcane	do.
Third year	Maize or fallow	Wheat
	or	
	Maize and *rahar* (mixed)	*Rahar*
	or	
	Maize, *rahar* and cotton (mixed)	*Rahar* and cotton
Rotation II—		
First year	Green manure (in sugarcane belt only)	Sugarcane
	Maize, *juar*, *ragi* or groundnut or fallow	do.
Second year	Sugarcane	Wheat, barley or gram or mixture of these
Third year	Fallow or maize	*Rahar*
	or maize and *rahar* mixed or early paddy	Green or gram and linseed mixed or peas or *rabi* cereales or cane
Rotation III—		
First year	Maize or *marua*	Wheat or barley or barley with gram and peas or gram with mustard and linseed
	or maize and *marua*, *rahar*	*Rahar*

—	*Kharif*	*Rabi*
Second year	Fallow or pulse crop	Wheat alone or wheat and mustard or wheat and chillies or tobacco or potatoes
Third year	Fallow	
Fourth year	Maize	Wheat or barley alone or mixed with mustard, linseed

7.—*Bengal Province—Northern Circle*

Rajshahi District	*Kharif*	*Rabi*
First year	Jute	Transplanted *aman*, *khesari*, lentil, mustard, wheat, etc. (or any of the above crops)
	Sugarcane	Sugarcane
Second year	*Aus* paddy	Transplanted *aman*, *khesari*, lentil, mustard, wheat, etc. (or any of the above crops)
	Jute and sometimes *aus* paddy	do.

N.B.—In low land and *khear* tracts only *aman* paddy is grown where no rotation is followed

Dinajpur District

Aus paddy is followed by 1. *khesari* 2. barley 3. onion. *Aman* paddy is followed by 1. *aman* paddy 2. gram or lentil 3. mustard 4. English vegetables 5. *kali* 6. *aman paddy*

Pabna District

1. *Aus* or broadcast *aman* is followed by either of the following in the *rabi* season

   Wheat, pulses, sugarcane, or sannhemp for fibre

2. Sugarcane is followed by *aus* paddy or jute or *jowar*
3. In the low lying *char* land or on the banks of the river *aus* and broadcast paddy is followed by wheat, barley or pulses

Jalpaiguri District

1. *Aman* is grown year after year in the same land without any (*kharif*) rotation
2. *Aus* (*kharif*)—motihari tobacco (*rabi*) to a certain extent

3. Barley (*rabi*)—*aus* of jute or fallow (*kharif*)—motihari tobacco (*rabi*) followed a little
4. Jute (in *kharif*)—aman grown in the same season of the year in low land or motihari tobacco (in the *rabi* season in high land)
5. Tobacco, *bengi* variety (*rabi*)—fallow (*kharif*)—tobacco or in some land *kalai* (*rabi*)

Rangpur District

Paddy followed by wheat, potato, barley, *khesari*, etc. (one year rotation)

Bogra District

Sandy loamy tract	Broadcast *aus* paddy	In *kharif* season
or jute is followed by potato		do.
Pulses like *kalai* or		*Rabi* season
Pulses like *kalai* or lentil or wheat or barley		do.
Clayey low lying areas.	Transplanted or deep water paddy or	*Kharif* and part of *rabi*
Sugarcane		*Kharif and rabi*
Transplanted paddy (in limited areas)		*Kharif* and part of *rabi*
Khesari or pulses	do.	*Rabi*

Darjeeling District

Maize is followed by *marua* or one of the pulses soya bean, *mashaym*, *kalai wrid*, *kulthi*, potato. When either of these is used it grows in its early stages in between the maize. Or, one of the following is grown after the harvest of maize barley, buckwheat *uwa* wheat, mustard or rape. After harvest of *aman* paddy either wheat, barley, buck wheat, or potato is grown.

Rotations in Assam

Being a pre-eminently paddy area, and as it is very difficult to grow any other substitute crop in the paddy fields, systematic rotations are unknown. On limited areas called sugarcane area, vegetable area, etc., the following are practised, viz., Sugarcane—ratoon—*aus* paddy and pulses—sannhemp and sugarcane. Jute land. Jute or *aus* paddy followed by pulses, oilseeds, potatoes and other vegetables. Vegetable area : *Colocasia antiquorum*—early *aus* paddy—potato, radish, brinjal, chillies, sweet potato, etc.

Panjab Province

Montgomery Circle. Irrigated tracts (1) Wheat—gram—wheat. (2) Wheat *toria*—cotton. (3) Wheat—maize—*senji*—sugarcane, (4) Rice-berseem-cotton.

(5) Rice-gram. (6) Rice-wheat. (7) Wheat-cotton-sugarcane. (8) Wheat-*kharif* fodders-gram. Rainfed areas. (1) Wheat-*bajri* or *jowar*. (2) *Bajri*-fallow-wheat. (3) Wheat-green gram and gingelli-fallow. (4) Wheat-gram.

Jullunder Circle. Kangra (1) Wheat-rice-green gram. (2) Wheat-linseed. Hoshiarpur under well irrigation (1) Tobacco-maize-potatoes. (2) Maize wheat-tobacco. (3) Cotton-*methi*-sugarcane-wheat. (4) Wheat-*jowar* and cluster beans or *jowar* alone.

Rainfed area. (1) Cotton-fallow-cotton. (2) Cotton-fallow or *jowar* and *matki*-cotton. (3) Wheat-maize. (4) Wheat or gram-*jowar*-cluster beans or *bajri*. (5) Wheatgreen gram and gingelli-fallow.

Sailab areas. (1) Rice-fallow-rice. (2) Wheat-rice. (3) Wheat-rice-*senji* or berseem-rice.

Jullunder and Ludhiana. (1) Wheat-maize-sugarcane-*senji*. (2) Wheat-*jowar*-and cluster beans-gram-cotton. (3) Tobacco-maize-potato. (4) Rice-wheat. (5) Maize wheat. (6) Maize-*senji*-tobacco.

Ferozepore. (1) Rice-gram. (2) *Jowar*-gram. (3) *Bajri*-cotton-wheat. (4) Maize-sugarcane-wheat. (5) Wheat-fodder crop-cotton.

Upper Assam Division. (1) *Ahoo* followed by mustard, pulses, wheat and potato, in the riparian tracts. (2) Sugarcane followed by jute or fallow. Lower Assam Valley. (1) *Aus*-mustard and lentils-*aus* or jute. (2) Wheat-*aus*-wheat. (3) *Aus*-pulse or mustard-*ahoo* or jute. (4) Sugarcane-ratoon-fallow-*aus*. (5) *Aman*-pulse aman. (6) Jute-mustard-*aus*-jute.

Central Provinces

In the Eastern districts of the province, on heavier *rabi* soils which are not bunded the rotation followed is :

First year. *Rabi* wheat, linseed or gram according to soil and moisture.

Second year. *Kharif* crop. *Kodo*, *rahar*, *til* mixture.

In bunded *rabi* fields a rotation of wheat, gram and linseed is followed.

In the Southern districts of the province, common crop rotations are as follows :

Main crop	Rotation crop	——
	First year	Second year
Rice	This is generally not rotated Lakori, udid and sometimes linseed is taken as a utera crop on heavy soils only	
Jowar	Groundnut	Cotton
Bajri	Groundnut or *tur*	Cotton

Main crop	Rotation crop — First year	Rotation crop — Second year
Wheat	Gram and pulse other crop	Linseed
Maize	Groundnut or *mug* or *udid*	*Tur* or mot
Ragi	*Kutki*	Niger
Gram	Wheat	Linseed
Cotton	*Jowar*	Groundnut
Groundnut	Cotton	*Jowar*
Sugarcane	Chillies	Paddy

In the Northern districts, the rotations are :

Crop	Rotations followed
Rice	Light soils-rice after rice Light bunded soils-rice followed by *utera* of leguminous crops or linseed. Heavy bunded soils-rice-wheat or any crops including gram, *masur*, *teora*, peas, etc., or linseed.
Jowar	*Jowar*-groundnut and cotton in cotton tract, and in non-cotton tract followed by *til*, sann, *tur*, *udid*, alternatively.
Wheat	Wheat mixed with gram. Wheat mixed with gram and *teora*, Wheat followed by leguminous crops as gram, *masur*, *teora*, peas, etc., then wheat followed by linseed and leguminous crops.
Gram	As shown under wheat.
Cotton	As shown under *jowar*.
Groundnut	As shown under *jowar*.
Sugarcane	Rotated with potatoes or vegetable crops or irrigated wheat.

In Eastern Berars, the rotations are :

(1) Cotton, *jowar*, groundnut. (2) Cotton, wheat, cotton, *jowar*. (3) Cotton *juar*. (4) Wheat, wheat, linseed, or gram.

In Western Berar, the rotations are :

(1) Cotton, *jowar*, groundnut. (2) In *ghat taluqs*, it is cotton ; *jowar*, cotton or groundnut, wheat. (3) In Pur valley it is cotton, cotton, wheat or *jowar*.

Bombay Province

The following rotations are selected as those largely prevalent, from among the districtwise rotations, furnished by the Director of Agriculture :—

Ahmedabad District	(A) First year—cotton, second year—*jowar*. (B) do. Cotton, do. *jowar*, third year-groundnut.

	(C) First year Cotton, *jowar* or *bajri*, second year—groundnut.
	(D) do. Cotton, second year—*bajri*, third year—groundnut.
Kaira District	*Bajri* mixture—*kodra* mixture—*bavto* mixture—dry tobacco.
Broach District	Cotton—*rabi jowar*.
	Cotton—*rabi jowar*—lang.
Panch Mahals	*Kharif* maize, *rabi* wheat and gram—groundnut, *bajri*—groundnuts.
Thana District	Rice after rice ; if there is moisture then gram, *tur* and *val* are taken in the *rabi*.

On Varkas land. *Rale* and pulses—*nagli* or *vari*—*niger*—fallow—fallow *Rale* and pulses—rice—*nagli* or *vari*—*niger*—fallow.

Central Division

(1) Rice and pulses in the same year
(2) Cotton—groundnut—*jowar*
(3) Cotton-groundnut-wheat or gram
(4) Sugarcane-cotton-*nilwa* in *kharif* and gram in *rabi*
(5) *Bajri*-groundnuts-cotton
(6) Sugarcane-ratoon-cotton in *kharif* and gram in *rabi*

Southern Division

(1) Rice—spelt wheat or gram
(2) Rice—rice or sugarcane, or rice in *kharif* and pulse in *rabi*
(3) Rice—irrigated *jowar* or chillies
(4) *Jowar*—cotton-wheat
(5) *Rabi* jowar-wheat and gram, pure or mixed with oilseeds like safflower
(6) *Bajri*—spelt wheat (under irrigation)
(7) *Bajri*—navane or *bajri*
(8) *Bajri*—*kulthi*-*kharif jowar*
(9) Ragi—*kulthi, save, nachani* or such millets
(10) Under canal irrigation—
  (*a*) Maize and sann in *kharif*-sugarcane
  (*b*) Maize and *tur* first year—maize, and sann in second, sugarcane in third
(11) *Rala*, followed by *kharif jowar* or pulses
(12) Wheat—*jowar* or cotton
(13) Wheat—irrigated cotton or chillies
(14) Groundnuts—*jowar* or cotton
(15) Groundnuts—irrigated spelt wheat

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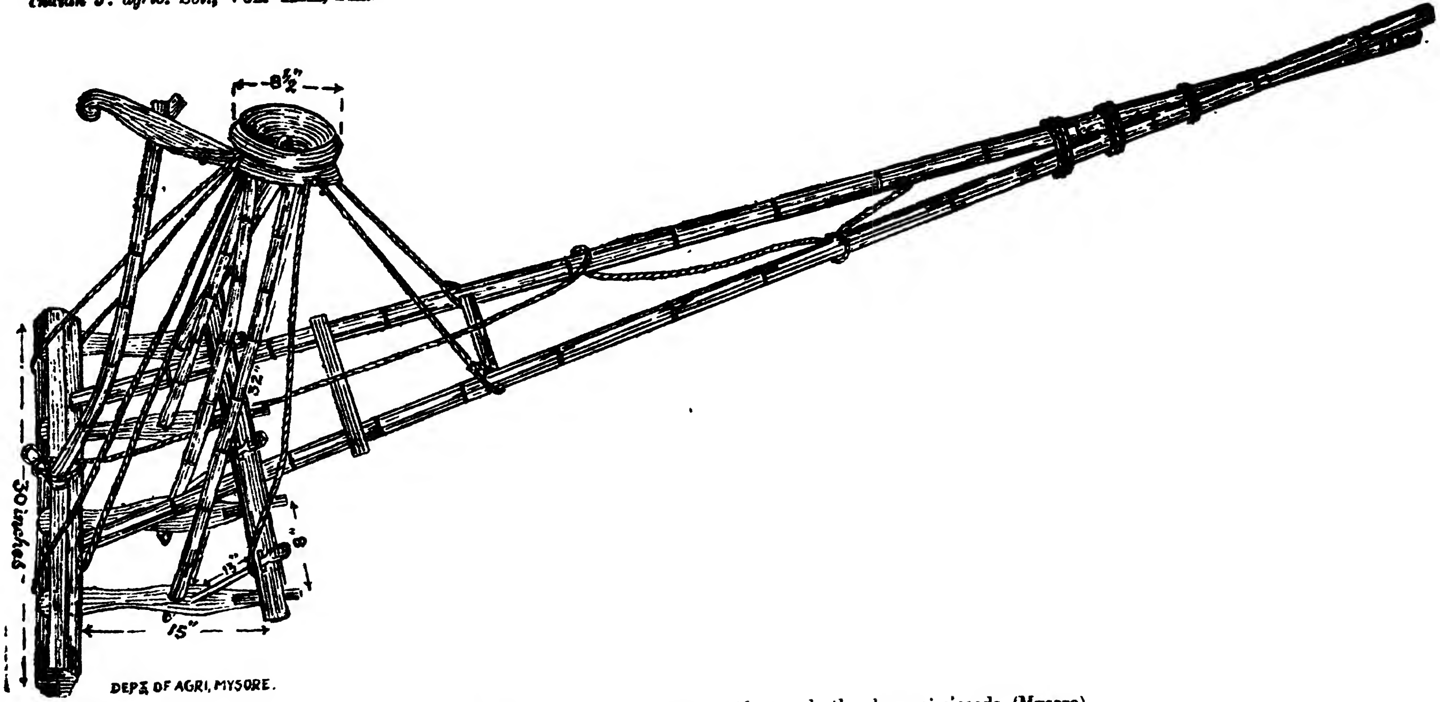

Fig. 1. Four-row drill, used for sowing rice (dry) and other large size seeds (Mysore)

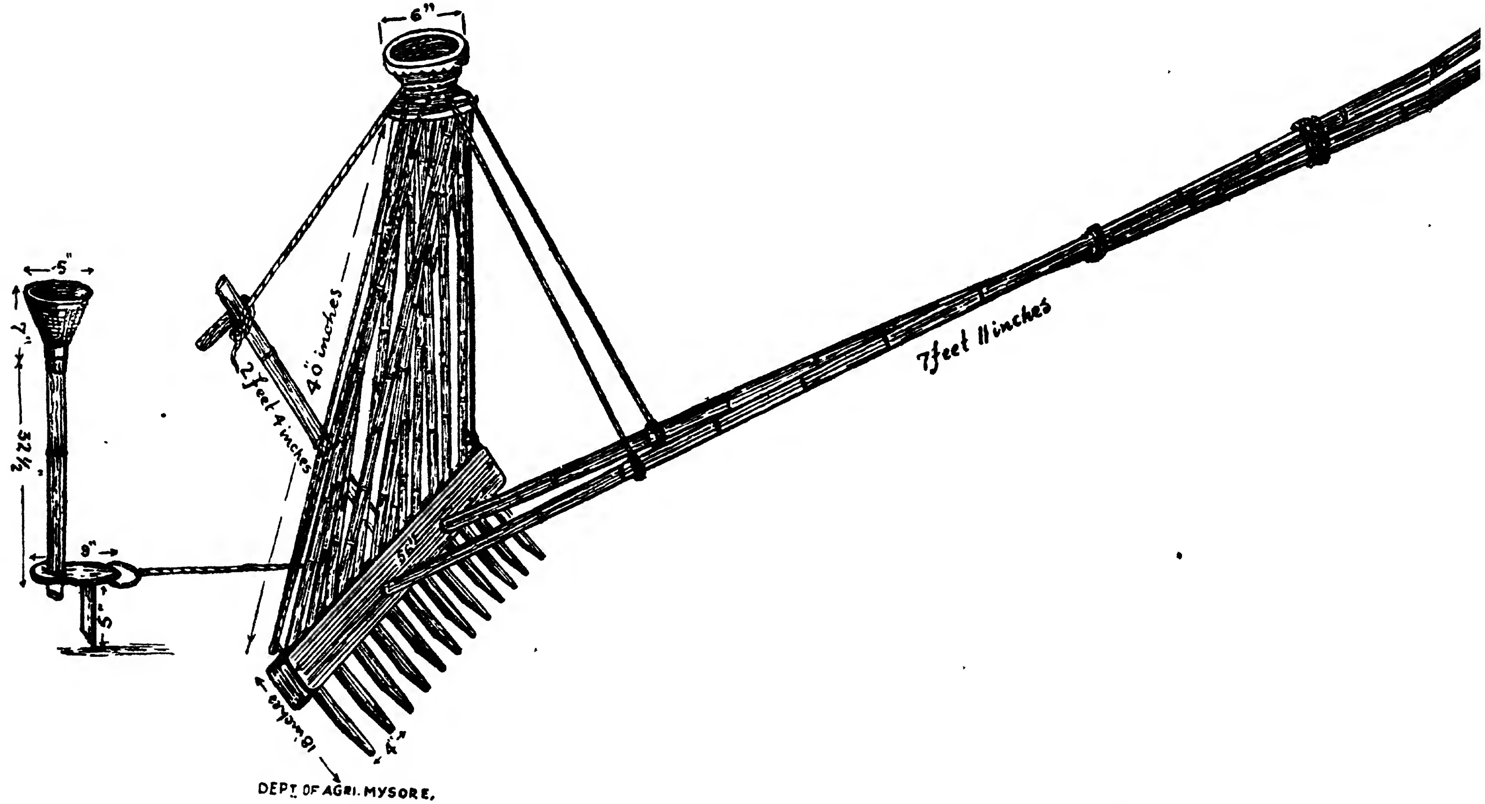

FIG. 2. The twelve-row seed drill for sowing *ragi*, with the one-row drill for sowing the mixed crop (Mysore)

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